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Marine Protected Areas off Alaska

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On the cover: Lingcod resting in symmetry on the underwater mountains of the Sitka Pinnacles Marine Reserve off the Alaskan coastline. Photograph by Victoria O'Connell, ADFG.

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Application of Marine Protected Areas for Sustainable Production and Marine Biodiversity off Alaska

DAVID WITHERELL and DOUG WOODBY

Introduction

Marine protected areas (MPA's) are an important tool for managing fisheries and other human activities in the ocean. As defined by Executive Order 13158 (Clinton, 2000), a marine protected area is "any area of the marine environment that has been reserved by Federal, State, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein."

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ABSTRACT—Fisheries managers have established many marine protected areas (MPA's) in the Federal and state waters off Alaska to protect ecological structure and function, establish control sites for scientific research studies, conserve benthic habitat, protect vulnerable stocks, and protect cultural resources. Many MPA's achieve multiple objectives. Over 40 named MPA's, many of which include several sites, encompass virtually all Federal waters off Alaska and most of the state waters where commercial fisheries occur. All of the MPA's include measures to prohibit a particular fishery or gear type (particularly bottom trawls) on a seasonal or year-round basis, and several MPA's prohibit virtually all commercial fishing. Although the effectiveness of MPA's is difficult to evaluate on an individual basis, as a group they are an important component of the management program for sustainable fisheries and conserving marine biodiversity off Alaska.

MPA's have been established to meet several goals, including conservation of biodiversity and habitat, increased scientific knowledge, educational opportunities, enhancement of recreational activities, maintenance of ecosystem services, protection of cultural heritage, and managing fisheries (National Research Council, 2001; Marine Protected Areas Federal Advisory Committee, 2005). For fisheries management, marine protected areas have been implemented to control exploitation rates of target species, protect spawning and nursery areas, improve sustainable yields, reduce bycatch of nontarget species, protect benthic habitat from perturbations due to fishing gear, ensure against uncertainties, conserve genetic diversity, or to achieve other objectives (National Research Council, 2001). MPA's are a critical element of ecosystem-based fishery management, which is being developed and promoted as the new approach to managing fisheries in the United States and elsewhere (Pikitch et al., 2004; Fluharty, 2005; Hoff et al., 2005).

Regional fishery management councils, established under the Magnuson-Stevens Fishery Conservation and Management Act, have the primary authority to develop marine protected areas that restrict fishing in Federal waters (5.6–370 km, or 3–200 n.mi. from the shoreline) of the United States. Regulations developed by the councils are subject to approval by NOAA's National Marine Fisheries Service (NMFS), acting on behalf of the Secretary of Commerce, before they can be implemented. NMFS can also restrict fishing activities if actions taken by a regional council are insufficient to meet legal requirements for fisheries management. The International Pacific Halibut Commission has authority to enact conservation measures, including MPA's, for the Pacific halibut, *Hippoglossus stenolepis*, fishery. States can also develop MPA's in Federal waters to restrict activities of fisheries managed by the state and for those fisheries not subject to approved Federal fishery management plans.

Restrictions on fishing in state waters of Alaska (0–5.6 km or 0–3 n.mi. of the shoreline), including closure of areas to certain gear types or harvest of particular species, are enacted by the Alaska Board of Fisheries. Establishment of no-take reserves in state waters requires action of the Alaska State legislature.

Many marine protected areas have been implemented by fishery managers in the Federal waters off Alaska, and they are an important component of the precautionary management system[1] established to provide sustainable fisheries in the Alaska region (NMFS, 2001b). These MPA's are permanently designated in the Federal fishery management plans (FMP's) and in the implementing regulations governing the crab, *Chionoecetes* spp., *Lithodes* spp., and *Paralithodes* spp.; scallop, *Patinopecten caurinus*; Pacific salmon, *Oncorhynchus* spp.;

[1]The North Pacific Fishery Management Council's precautionary management approach is to apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively rather than reactively, to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future, as well as current, generations. The goal is to provide sound conservation of the living marine resources, provide socially and economically viable fisheries for the well-being of fishing communities, minimize human-caused threats to protected species, maintain a healthy marine resource habitat, and incorporate ecosystem-based considerations into management decisions.

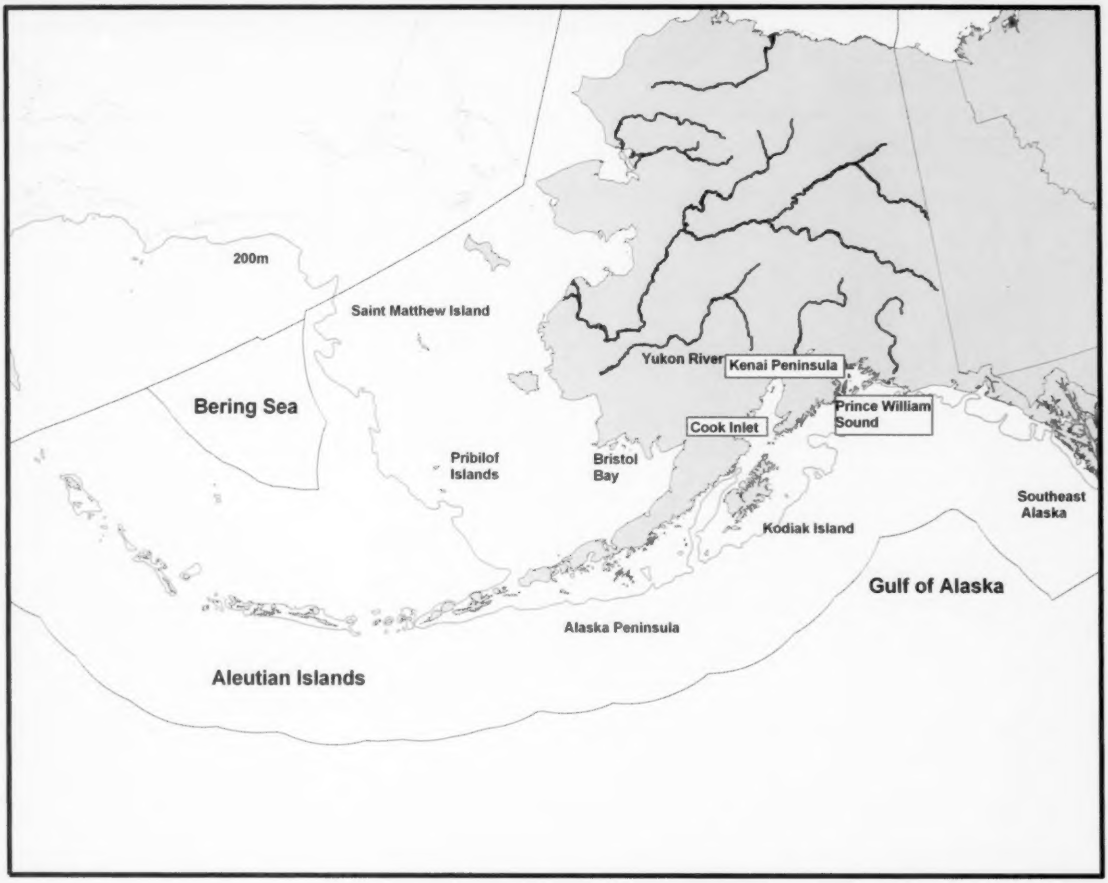

Figure 1.—Major geographic areas mentioned in the text.

and groundfish (Gadidae, Scorpaenidae, Hexagrammidae, Anoplopomatidae, and Pleuronectidae) fisheries.

State water closures to commercial fishery harvests have been enacted by the Alaska Board of Fisheries for research purposes and to conserve fish stocks, protect habitats, reduce bycatch, and provide subsistence and recreational harvest opportunities. These closures are enacted through regulations governing invertebrate dive fisheries, scallop dredge fisheries, crab pot fisheries, shrimp, *Pandalus* spp., fisheries, and various groundfish fisheries. There are also many closures affecting nearshore Pacific herring, *Clupea pallasi*, and Pacific salmon fisheries; however, these are primarily used to regulate harvests, such as prohibiting harvests in terminal areas for salmon, and are not included in this paper.

Fisheries management in the North Pacific region (Fig. 1) has generally been successful in achieving the conservation and management objectives of the Magnuson Stevens Act and is considered to be a model for other U.S. waters (U.S. Commission on Ocean Policy, 2004). Strict catch quotas for all managed target and nontarget species, coupled with an effective monitoring program, form the foundation of the Federal fishery management program. Other management measures, including MPA's, effort limitation, rights-based programs, community development programs, and protected resources considerations combine to provide a comprehensive conservation and management program (Witherell et al., 2000). As a result of these measures, sustainable production has been maintained. Annual groundfish harvests have been in the 3- to 5-billion pound range for the past 30 years (NPFMC, 2004a). Additionally, all groundfish, salmon, and scallop stocks, and most crab stocks managed by Federal FMP's, are considered to be above established minimum stock size thresholds (NMFS, 2004a).

This paper provides a comprehensive inventory and classification of MPA's in Federal waters off Alaska, a brief history of their development, and an

Table 1.—Summary MPA classification system developed by the National MPA Center (National MPA Center, 2005).

Criteria	Type	Use
Primary conservation goal	Natural heritage	Established to sustain biological communities, habitats, and ecosystems for future generations
	Cultural heritage	Established to protect submerged cultural resources
	Sustainable production	Established to support continued extraction of renewable resources
Level of protection	No access	Restricts all access into area except for research monitoring or restoration
	No impact	Prohibits all extraction, discharge, disposal, or other disturbance
	No take	Prohibits extraction of natural or cultural resources
	Zoned with no-take areas	Multiple use areas, with some areas where all extraction is prohibited
	Zoned multiple use	Allows some extractive activities throughout, but zoned to reduce some adverse impacts
	Uniform multiple use	Applies constant level of protection across entire protected area
Permanence of protection	Permanent	Legal authorities protect areas in perpetuity for future generations
	Conditional	Areas that have potential to persist over time, but legal authorities must be renewed
	Temporary	Areas that are designated for a finite duration, with no expectation of renewal
Constancy of protection	Year-round	Constant protection throughout the year
	Seasonal	Protection for only a portion of the year
	Rolling	Protection for finite duration, then de-designated and moved to another location
Scale of protection	Ecosystem	Measures intended to protect entire ecosystem or habitat within its boundaries
	Focal resource	Measures intended to protect one or more identified resources
Allowed extractive activities	No restrictions	All forms of extraction allowed
	Managed extraction	Allows extraction of resources but with regulatory restrictions within MPA
	Commercial fishing only	Prohibits all fishing except for commercial fishing
	Recreational fishing only	Prohibits all fishing except for recreational fishing
	Recreational catch-and-release fishing only	Prohibits all fishing except recreational catch and release
	Subsistence extraction only	Allows extraction of resources only for subsistence uses
	Scientific/educational fishing only	Allows extraction of resources only for scientific or educational purposes

examination of their effectiveness to date at achieving objectives. We also provide an accounting of adjacent state water MPA's for marine fisheries using the same classification scheme.

Methods

MPA's have been classified many different ways. The most recent classification system was developed by the National MPA Center, established within the National Oceanic and Atmospheric Administration. The MPA Center classifies MPA's based on six fundamental characteristics of design and management: primary conservation goal, level of protection, permanence, constancy (year-round or seasonal), scale, and allowed extractive activities as detailed in Table 1 (National MPA Center, 2005). We classified MPA's in the Federal and state waters off Alaska using this system.

Further, we categorized the MPA's based on their primary management objective. Adapting from the categories developed by Coleman et al. (2004) for Gulf of Mexico fishery MPA's, we categorized the North Pacific fishery MPA's into five groups: those primarily intended to protect ecological structure and function, establish control sites for scientific research studies, conserve habitat, protect vulnerable stocks, or protect cultural resources.

We researched the history and development of marine protected areas by examining available literature and reviewing the analytical reports and meeting records of the North Pacific Fishery Management Council (Council) and the Alaska Board of Fisheries. Additionally, we augmented these reports and records with personal observations (Witherell) as an analyst for the Council. We evaluated the effectiveness of the MPA's from a conservation perspective by examining available reports and reviewing the most recent information (biomass trends, trends in year-class strength) on the status of the stocks, including nontarget species (e.g. NPFMC, 2004b, 2004c, 2004d).

Based on the MPA Center criteria, MPA's are not included here if they were closed primarily to avoid fishing gear conflicts or if area-based regulations were established solely to limit fisheries by quota management or to facilitate enforcement. These include areas designated for testing trawl gear, regulatory areas and subareas, TAC allocation areas, harvest limit areas, sector allocation areas, and other types of designated marine managed areas. These sites may not meet the MPA definition of Executive Order 13158 in that they do not provide "lasting protection" for the natural or cultural resources.

Results

Area closures have long been used as a fishery management tool off Alaska, and the application of MPA's (the current term for area closures) has evolved to meet changing management needs. Beginning in 1939, trawling for red king crab, *Paralithodes camtschaticus*, was prohibited in Cook Inlet and all waters east of long. 150°W to limit the catch of red king crab and Pacific halibut taken by foreign trawl fleets. Later, in 1961, Japan established a no-trawl zone in Bristol Bay to limit interactions between its trawl fleet and its crab pot fleet. Many other MPA's were established off Alaska in subsequent years through international agreements with Japan, the Soviet Union, Republic of Korea, and Poland prior to implementation of preliminary fishery management plans in 1977 (Fredin[2]). The preliminary groundfish fishery management plans closed many areas to foreign trawling year-round and/or seasonally to protect domestic fisheries for crab, sablefish, *Anoplopoma fimbria*, and Pacific halibut from that competition. As the domestic

[2]Fredin, R. A. 1987. History of regulation of Alaska groundfish fisheries. U.S. Dep. Commer. NOAA, Natl. Mar. Fish. Serv., NWAFC Proc. Rep. 87-07, 63 p.

Table 2.— MPA inventory and management measures for fisheries in Federal and state waters off Alaska.

MPA objective and site name	Approx. size of site (n.mi.^{2})	Specific objective	Prohibited fishing activities
MPA's Primarily Intended to Protect Ecological Structure and Function			
Sitka Pinnacles Marine Reserve	3	Protect unique area	All bottom contact gear
Walrus Islands Closure Areas	900	Minimize disturbance	All groundfish fishing
Steller Sea Lion Mitigation Closures	58,000	Minimize potential competition	Pollock, cod, mackerel fisheries
Glacier Bay National Park	389	Protect park values	All fishing; some areas in phase-out
MPA's Primarily Intended to Improve Scientific Understanding			
Chiniak Gully Research Area	1,000	Provide control for fishing impact study	Pollock fishing
Southeast Alaska Dive Fishery Control Sites	45	Provide control for fishing impact study	Diving for urchins, sea cucumbers, or geoducks
MPA's Primarily Intended to Conserve Habitat			
Kodiak King Crab Protection Zones	1,500	Conserve red king crab habitat	Bottom trawling
Kodiak State Trawl Closure Areas	2,627	Conserve red king crab habitat	Bottom trawling
Cook Inlet Trawl Closure	7,000[1]	Conserve red king crab habitat	Bottom trawling
Alaska Peninsula Trawl Closure Areas	5,954	Conserve red king crab habitat	Bottom trawling
Scallop Dredge Closure Areas	12,000[1]	Conserve red king crab habitat	Dredging
Nearshore Bristol Bay Closure	19,000[1]	Conserve juvenile red king crab habitat	All trawling
Red King Crab Savings Area	4,000	Conserve red king crab adult habitat	Bottom trawling
Area 516 Seasonal Closure	4,000	Protect red king crab when molting	Bottom trawling
Pribilof Islands Habitat Conservation Area	7,000[1]	Conserve juvenile blue king crab habitat	All trawling
Southeast Alaska Trawl Closure	52,600	Protect corals and rockfish habitat	All trawling
Prince William Sound Trawl Closure Areas	1,485	Conserve benthic habitat and organisms	All trawling
Prince William Sound Groundfish Trawl Closure	4,054	Conserve benthic habitat and organisms	All groundfish bottom trawling except sablefish
Outer Kenai Peninula Groundfish Trawl Closure	1,093	Conserve benthic habitat and organisms	Bottom trawling for groundfish
St. Matthew Area Closure	331	Conserve blue king rearing habitat	All commercial fishing
Eastern Aleutian Islands Trawl Closure Areas	727	Conserve benthic habitat and organisms	All trawling
Aleutian Islands Habitat Conservation Area	277,100	Conserve essential fish habitat	Bottom trawling
Aleutian Islands Coral Habitat Protection Areas	110	Protect corals and rockfish habitat	All bottom contact gear
Gulf of Alaska Slope Habitat Conservation Areas	2,086	Conserve essential fish habitat	Bottom trawling
Gulf of Alaska Coral Habitat Protection Areas	67	Protect habitat of particular concern	All bottom contact gear in 13.5 n.mi.^{2}
Alaska Seamount Habitat Protection Areas	5,329	Protect habitat of particular concern	All bottom contact gear
Bowers Ridge Habitat Conservation Zone	5,286	Protect habitat of particular concern	Bottom trawling, dredging
MPA's Primarily Intended to Protect Vulnerable Stocks			
Commercial Salmon Fishery Prohibited Area	1,594,000	Limit mixed stock salmon fisheries	Salmon fishing with nets
Chinook Salmon Savings Areas	9,000	Control bycatch by groundfish trawlers	Trawling for pollock
Chum Salmon Savings Areas	5,000	Control bycatch by groundfish trawlers	Trawling for pollock
Halibut Longline Closure Area	36,300	Conserve juvenile halibut	Longlining for halibut
Herring Savings Areas	30,000	Control bycatch by groundfish trawlers	Trawling by target fishery
King and Tanner Crab Bycatch Limitation Zones	80,000	Control bycatch by groundfish trawlers	Trawling by target fishery
Snow Crab Bycatch Limitation Zone	90,000	Control bycatch by groundfish trawlers	Trawling by target fishery
Bogoslof Area	6,000	Conserve Aleutian Basin pollock stock	Pollock, cod, mackerel fisheries
State Waters Shrimp Trawl Fishing Closure Areas	2,022	Control bycatch and conserve shrimp stocks	Shrimp trawling
Resurrection Bay Lingcod Closure	112	Conserve Resurrection Bay lingcod stock	Lingcod fishing
Sitka Sound Lingcod Closure	243	Conserve Sitka Sound lingcod stock	Lingcod fishing
Black Rockfish Closure Areas	2,570	Conserve older black rockfish	Black rockfish fishing
Demersal Shelf Rockfish Closures	695	Conserve demersal shelf rockfish	Demersal shelf rockfish fishing
MPA's Primarily Intended to Preserve Cultural Resources			
Subsistence Crab Areas	1,500	Provide subsistence opportunities	Commercial crab fishing
Subsistence Halibut Areas	6,000	Provide subsistence opportunities	Commercial halibut fishing
Subsistence Sea Cucumber Areas	669	Provide subsistence opportunities	Commercial sea cucumber fishing

[1]Includes Federal and state water areas.

fisheries phased out the foreign fisheries in the 1980's, MPA's were primarily developed to control bycatch of species whose harvest is legally limited to other gear types (e.g. crabs can only be harvested with pot gear, but they are taken incidentally in trawl fisheries). By the 1990's, fishery managers off Alaska began to use MPA's to protect sensitive benthic habitat from the effects of mobile gear (particularly scallop dredges and bottom trawls), and to address concerns regarding potential competition with Steller sea lions, *Eumetopias jubatus*.

The current suite of MPA's developed for fisheries in the North Pacific can be categorized into several groups on the basis of the primary management objective identified. In many cases, the MPA's achieve multiple objectives, but in this study they were categorized based on their primary objective. An inventory list of the North Pacific fishery MPA's, grouped by category, is provided in Table 2. Table 3 shows how these MPA's are classified using the system developed by the National MPA Center (National MPA Center, 2005).

Details are provided for each MPA in the following sections, which are discussed by category of the primary management objective. We provide information, where available, on 1) the background and objective for the MPA, 2) the process to designate the MPA, 3) the size and location of the MPA, 4) the estimated costs to the fishing industry to implement the MPA, and 5) an examina-

Table 3.— Classification of MPA's for fisheries in Federal and state waters off Alaska.

MPA objective and site name	Primary conservation goal	Level of protection	Permanence of protection	Constancy of protection	Scale of protection	Allowed extractive activites
MPA's Primarily Intended to Protect Ecological Structure and Function						
Sitka Pinnacles Marine Reserve	Natural Heritage	No Take	Permanent	Year-round	Ecosystem	Scientific Fishing
Walrus Islands Closure Areas	Natural Heritage	Zoned With No-Take Areas	Permanent	Seasonal	Ecosystem	Scientific Fishing
Steller Sea Lion Mitigation Closures	Natural Heritage	Zoned With No-Take Areas	Permanent	Year-round/ seasonal	Ecosystem	Managed Extraction
Glacier Bay National Park	Natural Heritage	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Recreational Fishing
MPA's Primarily Intended to Improve Scientific Understanding						
Chiniak Gully Research Area	Natural Heritage	Uniform Multiple Use	Temporary	Seasonal	Ecosystem	Managed Extraction
Southeast Alaska Dive Fishery Control Sites	Natural Heritage	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
MPA's Primarily Intended to Conserve Habitat						
Kodiak King Crab Protection Zones	Sustainable Production	Zoned Multiple Use	Permanent	Year-round/ seasonal	Focal Resource	Managed Extraction
Kodiak State Trawl Closure Areas	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Cook Inlet Trawl Closure	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Alaska Peninsula Trawl Closure Areas	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Scallop Dredge Closure Areas	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Nearshore Bristol Bay Closure	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Red King Crab Savings Area	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Area 516 Seasonal Closure	Sustainable Production	Uniform Multiple Use	Permanent	Seasonal	Focal Resource	Managed Extraction
Pribilof Islands Habitat Conservation Area	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Southeast Alaska Trawl Closure	Natural Heritage	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Prince William Sound Trawl Closure Areas	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Prince William Sound Groundfish Trawl Closure	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Outer Kenai Peninula Groundfish Trawl Closure	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
St. Matthew Area Closure	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Ecosystem	Subsistence Extr.
Eastern Aleutian Islands Trawl Closure Areas	Sustainable Production	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Aleutian Islands Habitat Conservation Area	Natural Heritage	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Aleutian Islands Coral Habitat Protection Areas	Natural Heritage	No Take	Permanent	Year-round	Ecosystem	Scientific Fishing
Gulf of Alaska Slope Habitat Conservation Areas	Natural Heritage	Uniform Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
Gulf of Alaska Coral Habitat Protection Areas	Natural Heritage	Zoned With No-Take Areas	Permanent	Year-round	Ecosystem	Managed Extraction
Alaska Seamount Habitat Protection Areas	Natural Heritage	No Take	Permanent	Year-round	Ecosystem	Scientific Fishing
Bowers Ridge Habitat Conservation Zone	Natural Heritage	Zoned Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
MPA's Primarily Intended to Protect Vulnerable Stocks						
Commercial Salmon Fishery Prohibited Area	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Chinook Salmon Savings Areas	Sustainable Production	Uniform Multiple Use	Permanent	Seasonal Trigger	Focal Resource	Managed Extraction
Chum Salmon Savings Areas	Sustainable Production	Uniform Multiple Use	Permanent	Seasonal & Trigger	Focal Resource	Managed Extraction
Halibut Longline Closure Area	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Herring Savings Areas	Sustainable Production	Uniform Multiple Use	Permanent	Seasonal Trigger	Focal Resource	Managed Extraction
King and Tanner Crab Bycatch Limitation Zones	Sustainable Production	Zoned Multiple Use	Permanent	Seasonal Trigger	Focal Resource	Managed Extraction
Snow Crab Bycatch Limitation Zone	Sustainable Production	Uniform Multiple Use	Permanent	Seasonal Trigger	Focal Resource	Managed Extraction
Bogoslof Area	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Ecosystem	Managed Extraction
State Waters Shrimp Trawl Fishing Closure Areas	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Resurrection Bay Lingcod Closure	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Sitka Sound Lingcod Closure	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Black Rockfish Closure Areas	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Demersal Shelf Rockfish Closures	Sustainable Production	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
MPA's Primarily Intended to Preserve Cultural Resources						
Subsistence Crab Areas	Cultural Heritage	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Subsistence Halibut Areas	Cultural Heritage	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction
Subsistence Sea Cucumber Areas	Cultural Heritage	Uniform Multiple Use	Permanent	Year-round	Focal Resource	Managed Extraction

[1]Includes Federal and state water areas.

tion of how well the MPA has achieved its objectives to date.

Ecosystem MPA's

Sitka Pinnacles Marine Reserve

Off Cape Edgecumbe near Sitka, two small pinnacles rise from about 160 m, reaching to within 40 m of the ocean surface. Extensive observations made from submersible dives (O'Connell et al., 1998) have shown that the boulder field at the base of the pinnacles provides refuge for adult yelloweye rockfish, *Sebastes ruberrimus*; other demersal rockfish, *Sebastes* spp.; prowfish, *Zaprora silenus;* and lingcod, *Ophiodon elongatus;* as well as giant Pacific octopus, *Octopus dofleini*. The sides and top of the pinnacles are composed of columnar basalt, and gorgonian corals, *Primnoa* sp., grow on the steep walls of the pinnacles. Juvenile pelagic rockfishes, *Sebastes* spp., are abundant at the top of the pinnacles and in the water column above the pinnacles. The top of the pinnacles are covered with sessile invertebrates including anemones, tunicates, and hydrocorals, and adult lingcod aggregate there during the late spring and early summer (O'Connell, 1993).

In 1991, a few commercial fishermen had discovered the concentrations of lingcod on these pinnacles and experienced unusually high catch rates. Underwater investigations of the area by state fisheries biologists confirmed the large aggregations of lingcod and revealed the unique nature of the pinnacle area. State fishery biologists and managers were concerned about the risk of overfishing the concentrations of lingcod on these pinnacles and, beginning in 1997, implemented an emergency order to prohibit retention of all groundfish by commercial vessels in the vicinity of the pinnacles. However, the pinnacles quickly became a primary fishing ground for the charter boat and sport fleet, and in 1998, the Alaska Board of Fisheries permanently closed the pinnacle area to all state managed fisheries at the request of the local Fish and Game Advisory Committee. Public support for establishing a reserve was widespread as a result of a public outreach initiative (that included showing underwater footage from submersible dives on the pinnacles) by the local biologists and managers.

The state biologists also petitioned the Council to prohibit fishing for Federally managed species (including Pacific halibut) in the pinnacle area, thereby creating a comprehensive marine reserve. The Sitka Pinnacles Marine Reserve was implemented in 2000 as Gulf of Alaska (GOA) Groundfish FMP Amendment 59 (NPFMC, 1998). Regulations prohibit the use of all recreational and commercial fishing gear (except pelagic troll gear used for salmon), and anchoring by fishing vessels within a 10.3 km^2 (3 n.mi.^{2}) rectangular area encompassing the pinnacles (Fig. 2).

This MPA appears to be effective at protecting a post-spawning aggregation of lingcod, although comprehensive surveys of the lingcod population are lacking. Closure of this area is supported by the local fleet of commercial, charter, sport, and subsistence fishermen. Compliance with the MPA regulations appears to be high. Although there have been a few anonymous reports of violations to state biologists, no citations have been issued by enforcement personnel (O'Connell[3]).

Glacier Bay National Park and Preserve

In 1998, President William J. Clinton signed into law sweeping restrictions on commercial fishing in marine waters of Glacier Bay National Park in Southeast Alaska (Fig. 2). The law established a 449.3 km^2 (131 n.mi.^{2}) MPA closed to commercial fishing (effective in 1999) and another 885 km^2 (258 n.mi.^{2}) undergoing a commercial fishing phase-out. Closed areas include 216 km^2 (63 n.mi.^{2}) of wilderness waters[4] that formerly supported a productive Dungeness crab, *Cancer magister*, fishery and 233 km^2 (68 n.mi.^{2}) in the bay's upper reaches where tidewater glaciers have been receding. The remaining commercial fisheries for Tanner crab, *Chionoecetes bairdi*, halibut, and salmon will continue only for the lifetimes of the existing permit holders with a qualifying history. Fisheries for groundfish and king crab were ended, while the Tanner crab and Pacific halibut fisheries are restricted to just the middle and southern ends of Glacier Bay proper during the phase-out. Fisheries in Icy Strait and outside waters within three miles of shore continue as before.

The closures were enacted to protect park values, which were considered incompatible with commercial extraction and were not due to conservation concerns associated with commercial fishing. Recognizing the economic hardships imposed by the commercial fishing closures, the U.S. Congress approved an $8 million buy-out program for Dungeness crab fishermen and a compensation package of $23 million for other affected entities representing fishing permit holders (46.5%), crewmembers (8.4%), processors (21.1%), processor workers (1.7%), businesses (7.5%), communities that lost tax revenues (1.7%), and communities that suffered indirectly (13.1%).

Glacier Bay provides unique research opportunities on the effects of fisheries. Research in the reserve is focused on the effects of the closures on commercial fish species, including the potential efficacy of the reserves for crab and Pacific halibut that may cross reserve boundaries, and comparisons of Dungeness crab populations inside and outside of protected areas. Preliminary results indicated that, as expected, unfished areas accumulated larger populations of legal-sized male crabs (Shirley[5]). Notably not different between fished and unfished areas was limb loss, primarily the front claws, which was suspected to be an effect of handling in a commercial fishery and which affects survival, molting, and mating. In this case, the controlled experiment suggested the cause of limb loss was large predators, such as Pacific

[3]O'Connell, Victoria, ADFG, Sitka. Personal commun. 2004.

[4]The Wilderness Act of 1964 required designation of wilderness areas on Federal public lands. In 1980, when Glacier Bay National Monument was designated as Glacier Bay National Park and Preserve, >2 million acres of land and water received wilderness designation.

[5]Shirley, Tom, Univ. of Alaska, Juneau. Personal commun. 2004.

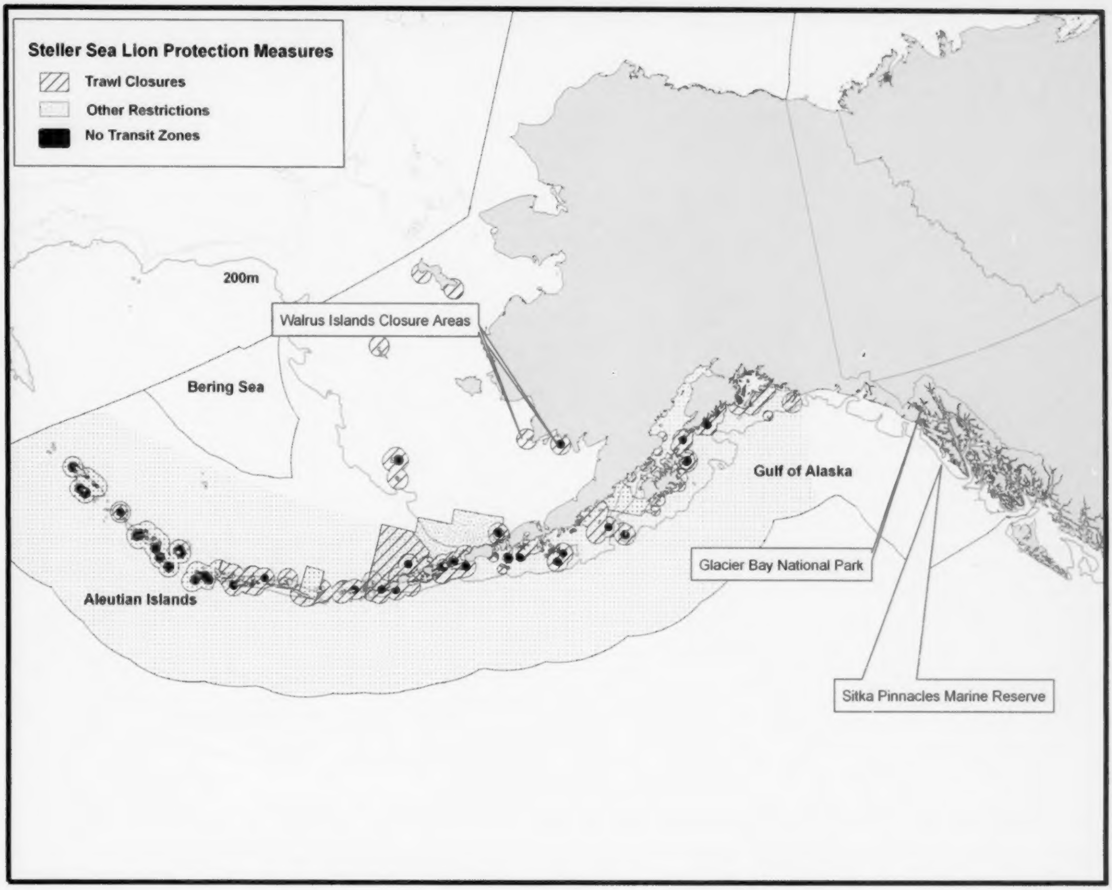

Figure 2.—MPA's designed to protect ecological structure and function.

halibut; sea otters, *Enhydra lutris;* river otters, *Lutra canadensis*; and Pacific octopus.

Walrus Islands Closure Areas

Pacific walrus, *Odobenus rosmarus divergens,* occur throughout the Chukchi and Bering Seas, with the southernmost major haulouts occurring in northern Bristol Bay on the islands of Round Island and the Twins, as well as on Cape Pierce. These haulouts are occupied by adult males during the spring and summer months when resting between foraging trips for invertebrates throughout Bristol Bay. Although the incidental catch of Pacific walrus in groundfish fishing operations was rare, the potential disruption of animals on their haulout sites or during feeding was of concern to Federal biologists and also to Alaska natives who hunt Pacific walrus for subsistence uses.

Biologists studying Pacific walrus at these haulouts had noticed that their numbers declined over the season, coincident with fishing effort by trawl vessels targeting yellowfin sole, *Limanda aspera,* in the spring once the ice sheet had retreated. Biologists believed that sound from the vessels could potentially be disrupting acoustic communication of these animals, both in the air and water environments, and proposed a 22.2 km (12 n.mi.) boundary around haulouts to reduce acoustical disruption.

Based on an analysis of this proposal, the Council developed regulations to prohibit all vessels from fishing for groundfish species within 22.2 km (12 n.mi.) of Round Island, the Twins, and Cape Pierce in northern Bristol Bay, during the period from 1 April through 30 September (Fig. 2). It was estimated that this regulation cost the fleet up to $4 million in lost ex-vessel revenues, based on 1988 catches and prices (NPFMC, 1991). This MPA, which totals 3,087 km^2 (900 n.mi.^{2}), was first established as a temporary measure in 1989 under

Bering Sea and Aleutian Islands (BSAI) Groundfish FMP Amendment 13, and it was implemented as a permanent measure under Amendment 17 in 1992 (NPFMC, 1991). In conjunction with the Federal action, a no-transit zone, except by permit, was established by the Alaska Board of Game for vessels within 5.6 km (3 n.mi.) of Round Island in the Walrus Island State Game Sanctuary.

The Walrus Islands closures may have substantially reduced effects of acoustic disturbance based on observations that more Pacific walrus occupy the haulouts throughout the summer now than before the closures (Seagars[6]). Nevertheless, it may be impossible to ascertain the impact of the MPA on the Pacific walrus population as a whole. The population had been reduced by commercial exploitation to a low in the mid 1950's, and by the late 1970's it had apparently recovered to pre-exploitation levels of 200,000 to 250,000 animals (Angliss and Lodge, 2002).

Steller Sea Lion Mitigation MPA's

The western stock of Steller sea lions declined about 80% between the 1950's and the late 1980's, and was listed as threatened under the Endangered Species Act in 1990 by emergency rule. Multiple factors, including fishery related effects, likely played a role in the decline (National Research Council, 2003). At the time of listing, NMFS enacted several regulations to reduce direct mortality as a result of fishing, including no shooting at sea lions, a reduced incidental catch limit, and establishment of 5.6 km (3 n.mi.) radius no-entry buffer zones around all rookeries to reduce disturbance and reduce opportunities for shooting at sea lions.

In 1991, NMFS completed a consultation on proposed groundfish harvest specifications, pursuant to Section 7 of the Endangered Species Act (ESA), and concluded that the spatial and temporal compression of Gulf of Alaska walleye pollock, *Theragra chalcogramma*, fisheries could create competition for prey and thus contribute to the decline of sea lions (Fritz et al., 1995). In response, NMFS prohibited trawling within a 18.5 km (10 n.mi.) radius of all rookeries in the Gulf of Alaska. In 1992, 18.5 km (10 n.mi.) radius trawl closures were also implemented around all rookeries in the Bering Sea and Aleutian Islands area.

Simultaneously, the Bogoslof area was closed to walleye pollock fishing, and concerns about the redistribution of effort led to a seasonal extension of five Aleutian Islands rookeries from 18.5 km (10 n.mi.) to 37 km (20 n.mi.) through 15 April each year. The western stock of Steller sea lions was listed as endangered in 1997, and in 1999, trawling for pollock was also prohibited within 18.5 km (10 n.mi.) of major haulout areas, with some closures extending out to 37 km (20 n.mi.).

In November 2000, NMFS completed another ESA Section 7 consultation on the groundfish fisheries and concluded that proposed fisheries for walleye pollock; Pacific cod, *Gadus macrocephalus*; and Atka mackerel, *Pleurogrammus monopterygius*, would jeopardize the continued existence of Steller sea lions and adversely modify their critical habitat due to potential prey competition and modification of their prey field (NMFS, 2000). To bring the fisheries into compliance with the ESA, the Council established a large stakeholder committee to develop fishery management measures that would address the concerns about prey competition and still allow viable fisheries to be prosecuted.

The committee developed the alternative that was adopted by the Council in October 2001 and implemented by NMFS for 2002 and thereafter. Management measures adopted were gear, fishery, and area specific and provide full or partial closure to 198,940 km^2 (58,000 $n.mi.^2$) of the ocean, and other measures throughout the Aleutian Islands and much of the Gulf of Alaska (Fig. 2). Implementation of this complex suite of MPA's for Steller sea lions was projected to result in losses of $2.6 million to $14.0 million in ex-vessel revenue to the harvesters and a loss of 15 to 411 full-time jobs in the harvesting and processing sectors (NMFS, 2001a).

The Steller sea lion mitigation MPA's included no-transit zones within 5.6 km (3 n.mi.) of 37 rookeries in the Gulf of Alaska (excluding southeast Alaska) to protect Steller sea lions from disturbance. These no-transit zones, including the 5.6 km (3 n.mi.) zone around Round Island to protect Pacific walrus, are truly no-take reserves with no allowance for recreational fishing, and are the only such marine reserves in Alaska. Despite the preponderance of evidence indicating that nutritional stress is not a primary threat to recovery of Steller sea lions (National Research Council, 2003), it is likely that the no-transit zones will stay in effect until the endangered status of Steller sea lions is resolved.

In addition to mitigating potential effects of fishing on Steller sea lions, the MPA's also offer localized protection to deep-sea coral and sponge communities along the Aleutian Islands. Submersible observations have found areas with complex coral and sponge communities within the areas encompassed by the MPA's, although the absolute amount of protection to this habitat has not been quantified. Additional submersible research to understand the distribution of corals and sponges in the North Pacific is planned or ongoing (Stone[7]).

Scientific Research MPA's

MPA's can provide scientific control sites to distinguish natural variability from human impacts such as fishing activities (Lindeboom, 2000; National Research Council, 2001). Scientific research MPA's have been imposed in the Alaska EEZ on a temporary basis when the need arises. For example, a seasonal MPA was established in the Bering Sea west of Cape Sarichef during the years 2003–05, to test the hypothesis that intensive trawl fishing may create a local depletion of Pacific cod, an important prey item for Steller sea lions (NMFS, 2002). Although the MPA was scheduled to also be in effect for 2006, NMFS determined that the MPA was no longer necessary because the study had overwhelmingly concluded

[6]Seagars, Dana, USFWS, Anchorage, Alaska. Personal commun. 2004.

[7]Stone, Robert, NMFS Auke Bay Lab., Juneau. Personal commun. 2005.

that there were no differences in Pacific cod abundance between the intensively trawled areas and the untrawled control areas (Logerwell[8]).

Chiniak Gully

In 2001, scientists from the NMFS Alaska Fisheries Science Center (AFSC) began an investigation of the effects of fishing on Steller sea lion prey (walleye pollock and capelin, *Mallotus villosus*) abundance and distribution in commercial trawl fishing grounds located on the east side of Kodiak Island. The sampling design uses control (unfished) and treatment (fished) areas of Chiniak and Barnabas gullies, respectively. Regulations were established to close Chiniak gully to trawl fishing from 1 August through 20 September during 2001–04. In 2005, scientists at the AFSC apprised the Council that they were interested in reestablishing the Chinak gully research closure for 2006 through 2010 to collect additional data. In February 2006, the Council reviewed the analysis (NMFS, 2006), and recommended that this research closure be reestablished under the condition that if the study cannot occur in any of these years, or if the research is completed prior to 20 September, then the Chiniak gully should be opened for fishing as soon as possible.

Southeast Alaska Dive Fishery Research Areas

When the dive fishery management plans were developed by the State of Alaska in the 1990's for sea cucumbers, *Parastichopus californicus*; red sea urchins, *Strongylocentrotus franciscanus;* and geoduck clams, *Panopea abrupta,* in southeast Alaska, sections of shoreline were closed to harvests as control sites for these species singly or in combination. These sites, in southern southeast Alaska, are surveyed on an annual or nearly annual basis to estimate biomass and size compositions. Comparisons of population characteristics between the control and harvest sites are made to evaluate the extent to which population changes might be due to fishing or to environmental variation. To date, the effects of fishing, relative to natural variation, have been small due to conservative quotas.

Habitat Conservation MPA's

Kodiak King Crab Protection Zones

The fishery for red king crab stocks in the Kodiak Area of the Gulf of Alaska declined sharply in the late 1960's and, following a brief period of recovery, they declined again in the mid and late 1970's (Zheng et al., 1996). These declines were likely due to a combination of factors including overfishing and changing oceanographic conditions (Kruse, 1996). State and Federal fishery managers sought to take whatever actions were necessary to provide recovery of this stock. Beginning in 1982, the fishery was closed, and other fisheries were displaced to limit bycatch and habitat effects of fishing. With no signs of recovery by the end of 1985, the Alaska Department of Fish and Game proposed that emergency action be taken to implement bottom trawl closures in areas around most of Kodiak Island.

Emergency regulations were implemented through June 1986, and the Council established an industry workgroup to develop a long-term solution to protect red king crabs from trawling-induced mortality, particularly during their molting period, and to protect habitat from potential impacts due to trawling. The workgroup recommendations were adopted by the Council as Amendment 15 to the GOA Groundfish FMP (NPFMC, 1986).

In 1987, three types of trawl closure areas were established on the south and east sides of Kodiak Island based on the use of areas by crab at different life stages (Fig. 3). Type I areas, totaling 3,430 km^2 (1,000 n.mi.^{2}), had very high king crab concentrations and, to promote rebuilding of the crab stocks, they were closed all year to all trawling except with pelagic gear. Type II areas, which total 1,715 km^2 (500 n.mi.^{2}), had lower crab concentrations throughout most of the year, but were closed to nonpelagic gear from 15 February through 15 June when crabs are molting and have higher bycatch mortality rates. Type III areas had been identified as important juvenile king crab rearing or migratory areas. Type III areas would be closed to trawling following a determination that a recruitment event has occurred. Originally established as a temporary measure while the stock recovered, the MPA later became established as a permanent measure for the Gulf of Alaska Groundfish FMP.

The red king crab stocks throughout the central and western Gulf of Alaska remain at very low levels, despite many management measures implemented over the years to minimize fishing mortality and conserve crab habitat. The MPA closures have been in place for nearly 20 years, yet their benefits are difficult to ascertain. They have certainly helped to control red king crab bycatch in groundfish fisheries by reducing the probability of a trawler encountering aggregations of crabs, as well as limiting any effects trawling may have on crab habitat. However, Type III closures have never been triggered due to a lack of recruitment, although pods of small red king crab juveniles continue to be observed in several bays of Kodiak Island. Adult and juvenile red king crab numbers remain low as measured by trawl surveys in and around the Kodiak trawl closure areas (Spalinger, 2005).

Cook Inlet Trawl Closure Area

Similar to the fate of many other Tanner crab and red king crab stocks in the Gulf of Alaska, the Tanner and red king crab populations in Cook Inlet declined dramatically in the 1980's. The king crab fishery has been closed since 1984 and the Tanner crab fishery has been closed since 1991. Nevertheless, the stocks continued to decline, and surveys indicated no signs of recovery (Bechtol et al., 2002).

Although bottom trawling had never been conducted in Cook Inlet to any extent, state fishery managers felt that it would be prudent to be proactive and prevent trawling from expanding into the area, thus eliminating the possibility of bycatch or habitat impacts. In 1995, the Alaska Board of Fisheries prohibited

[8]Logerwell, L. 2005. Fishery interaction team presentations to the North Pacific Fishery Management Council. U.S. Dep. Commer., NMFS/AFSC Quarterly Report April–June:36–37.

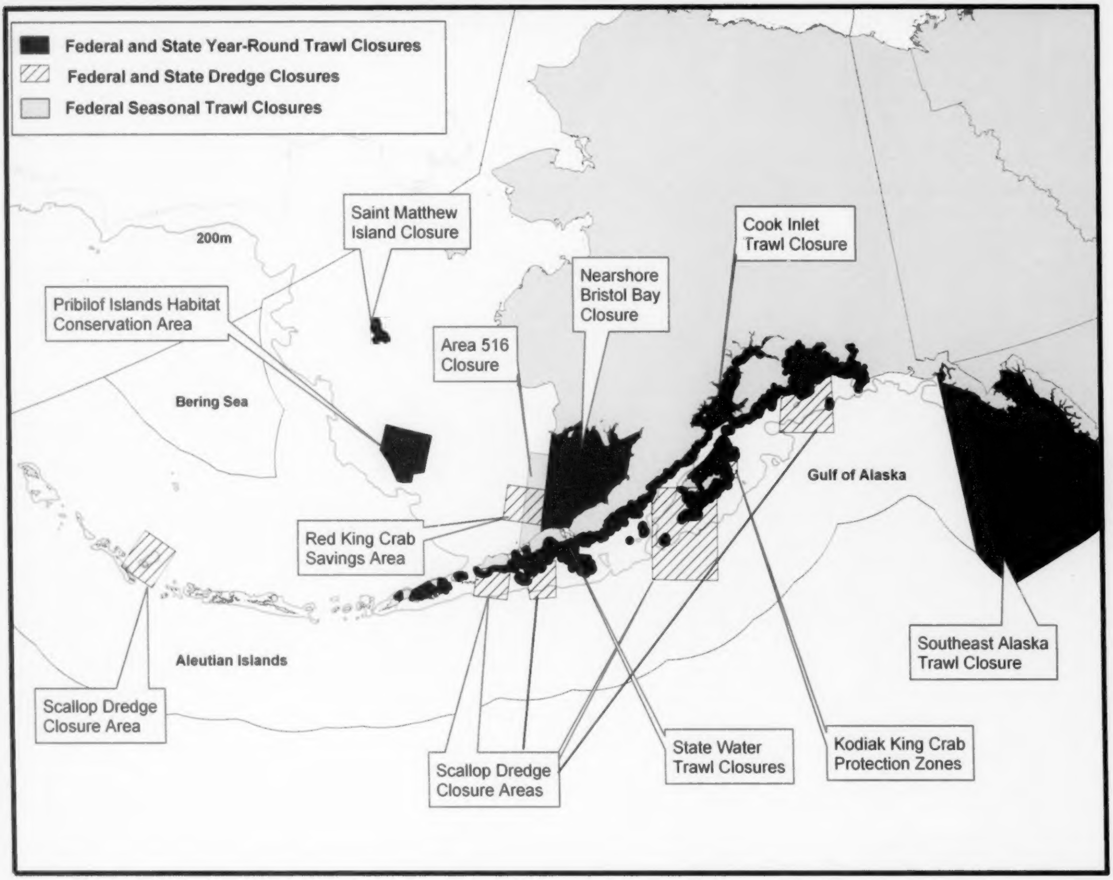

Figure 3.— MPA's designed to conserve fish habitat.

bottom trawling in state waters of Cook Inlet. The state proposed that the Council take complementary action for Federal waters, so the Council initiated an analysis of several alternatives to address the issue. In September 2000, the Council adopted an MPA that prohibited bottom trawling in all Federal waters of Cook Inlet (Fig. 3). This MPA was implemented in 2002 under GOA Groundfish FMP Amendment 60 (NPFMC, 2002).

The Cook Inlet Trawl Closure Area has only been in effect for a few years, and thus it is impossible to evaluate its effectiveness as an allocation or conservation measure. Recent trawl surveys have detected below-average numbers of juvenile Tanner crabs in Cook Inlet, and the red king crab stock remains at a very low level with no signs of rebuilding (Bechtol, 2005). In the absence of bycatch mortality and habitat impacts, there is little left for managers to do but wait for environmental conditions favorable for crab reproduction and survival.

Scallop Dredge Closure Areas

The weathervane scallop, *Patinopecten caurinus,* fishery has been managed by the State of Alaska since the inception of the fishery in the late 1960's (Shirley and Kruse, 1995). In 1998, the NMFS approved the Alaska Scallop FMP, delegating most authority to the State of Alaska to manage the scallop resources in the EEZ, including establishment of MPA's for this fishery. Concerns about crab bycatch in the scallop fishery and habitat effects due to scallop dredging prompted the Alaska Board of Fisheries to establish extensive closures to fishing with scallop dredges in state and Federal waters. Closures include Yakutat Bay; state and Federal waters south of Cordova, eastern Prince William Sound, Cook Inlet, Kachemak Bay and nearby state waters of outer Kenai Peninsula; most of the state waters surrounding Kodiak and Afognak Islands as well as a large block of Federal waters to the southwest of Kodiak; most of the state waters on the south side of the Alaska Peninsula; large bays of Akun, Akutan, and Unalaska Islands; and Petrel Bank

in the Aleutian Islands (Fig. 3). The state has also prohibited scallop dredging in the habitat conservation MPA's (no-trawl areas) adopted by the Council and NMFS in Bristol Bay and around the Pribilof Islands.

Nearshore Bristol Bay Trawl Closure Area and Red King Crab Savings Area

The Bristol Bay red king crab population collapsed in 1981 following a huge buildup in biomass and historic high catches. The cause of the collapse remains unknown, but it has been hypothesized by different scientists to be due to several factors including overfishing, discard mortality, trawl interactions, disease or other source of natural mortality, or reduced recruitment due to climatic events (Kruse, 1996). State fishery managers closed the fishery in 1982 and 1983.

The area in Bristol Bay where red king crabs were distributed, known as the "pot sanctuary," had been closed to foreign trawl fisheries since 1975 and to domestic trawl fisheries through the end of 1983, when Amendment 1 to the BSAI Groundfish FMP opened the area for the developing domestic trawl fisheries. This action raised concerns of state fishery managers and crab fishermen who requested that the Bristol Bay area be closed to all trawling to protect the remaining stock and their habitat from further impacts. In 1986, the Council adopted BSAI Groundfish FMP Amendment 10, which prohibited bottom trawling in central Bristol Bay where most crabs were found, encompassing about 27,440 km^2 (8,000 n.mi.^{2}). Unfortunately, surveys conducted in subsequent years failed to detect signs of recovery, and fishery managers again raised concerns that additional measures were needed.

To address these concerns, the Red King Crab Savings Area was established by emergency rule in 1995 as a year-round bottom trawl and dredge closure area (Fig. 3). This 13,720 km^2 (4,000 n.mi.^{2}) area was known to have high densities of adult red king crab and was thus assumed to be an important habitat area as well. Additionally, several additional options to reduce the impacts of trawling and dredging on red king crab stocks were considered by the Council, including time/area closures, bycatch limits, individual bycatch quotas, and penalties (Witherell and Harrington, 1996).

After further analysis and deliberation, the Council decided to implement an additional trawl closure area to protect juvenile red king crab and critical rearing habitat, which includes stalked ascidians and other living substrates (Ackley and Witherell, 1999). Beginning in 1997 BSAI Groundfish FMP Amendment 37 established a 65,170 km^2 (19,000 n.mi.^{2}) year-round closure to all trawling (bottom trawling and pelagic trawling) in all of Bristol Bay east of long. 163°W (Fig. 3). One small area within the Nearshore Bristol Bay MPA, bounded by long. 159° to 160°W and lat. 58° to 58°43′N, remains open to trawling during the period 1 April to 15 June each year. Analysis of observer data indicated that fisheries for yellowfin sole could be prosecuted within this area and not impact crab habitat or increase crab and Pacific herring bycatch (NPFMC, 1996).

The Red King Crab Savings Area also became permanent through Amendment 37. In adopting this MPA as a permanent measure, the Council provided for a limited bottom trawl fishery to occur in the Red King Crab Savings Area south of lat. 56°10′N, an area with historically high catch rates of rock sole. To ensure that this provision would not create allocation or conservation problems, the allowance for bottom trawling would only be made in years when there is a directed fishery for Bristol Bay red king crab using pot gear. If the fishery is to be open, a red king crab bycatch limit is established for this subarea, and vessels trawling for groundfish (mainly rock sole) can fish in the specified subarea until the bycatch limit is reached.

These MPA's, in combination with favorable environmental conditions, may have assisted in the recovery of the Bristol Bay red king crab stock. Survey information suggests that sessile benthic invertebrates used by juvenile king crab may be increasing in Bristol Bay (NPFMC, 2004d). Further, the red king crab stock has increased to biomass levels associated with maximum sustainable yield, and there are many year classes present in the population (NPFMC, 2004c). The red king crab fishery reopened in 1996, and annual catches have increased steadily, such that a conservative catch limit of 8,301 t (18.3 million pounds) was set for the season beginning in October 2005.

Area 516 Seasonal Closure

In 1987, when the central area of Bristol Bay was closed to trawling to protect red king crab, managers also decided to extend the closure further west on a seasonal basis to protect red king crab when they are in a fragile molting condition. This seasonal closure area, designated as Area 516, is closed to all trawling from 15 March through 15 June (Fig. 3). The central portion of the area became a year-round trawl closure in 1995, with the implementation of the Red King Crab Savings Area. The southern part of Area 516 remains open during the second part of the year, and most of the Bering Sea red king crab bycatch is taken in this area by bottom trawl vessels targeting northern rock sole, *Lepidopsetta polyxystra*.

Pribilof Islands Habitat Conservation Area

In 1989, the Central Bering Sea Fishermen's Association initiated a proposal to prohibit trawling around the Pribilof Islands to protect habitat for juvenile blue king crab, *P. platypus*, forage fish for marine mammals and seabirds, and maintain a stable ecosystem in the surrounding waters. The blue king crab population had decreased over 90% from a peak in 1975, and the fishery was closed entirely in 1988 due to low abundance.

The Council initiated an analysis of the proposal in 1991, and the analysis was revised several times to consider other boundary configurations. Through spatial display of NMFS survey data, groundfish observer data, and commercial crab fishery data, the analysis provided an understanding of blue king crab habitat and trawl fishing effort distribution. The area that was ultimately

selected was designed to include the vast majority of blue king crabs, while at the same time, allowing the trawl fishery access to the edge of the 100 m contour, which is economically important to trawl vessels targeting walleye pollock and Pacific cod. The yellowfin sole trawl fishery was negatively affected by the closure north and east of the Pribilof Islands, but the costs of the closure to this fleet were not quantified. In 1995, the 24,010 km^2 (7,000 n.mi.^{2}) Pribilof Islands Habitat Conservation Area was implemented by BSAI Groundfish FMP Amendment 21a, and the area was permanently closed to all trawling and dredging year-round (Fig. 3).

The Pribilof Islands Conservation Area has not been successful in rebuilding the blue king crab stock, although it may have served to limit the effects of trawl fisheries on juvenile crabs and habitat. Despite the protection offered by the MPA, and closure of the crab fisheries, the Pribilof Islands stock of blue king crab has continued to decline to very low levels and is considered to be in an "overfished" condition (NPFMC, 2004c). On the other hand, the Pribilof Islands red king crab stock seems to have benefited from the trawl closure, with increased abundance since 1996 (NPFMC, 2004c).

Southeast Alaska Trawl Closure

In 1991, longline fishermen from Sitka and other local citizens proposed that all trawling (using bottom trawls or pelagic trawls) be prohibited off southeast Alaska. The rationale for this was that trawling was causing long-term damage to deep-sea corals, conservation problems for Pacific rockfish, *Sebastes* spp. and *Sebastolobus* spp., and social disruption to the local fishing industry (Behnken, 1993). In evaluating this proposal, the link between coral use by rockfish and damage to rockfish habitat as a result of trawling was unknown. Rather than prohibit trawling entirely, the Council instead adopted a rebuilding plan for Pacific ocean perch, *Sebastes alutus*, the primary rockfish species in the area fished by trawl gear.

Although the original MPA proposal was not adopted when brought to the Council for final decision, it was later adopted as part of the license limitation program that was implemented under GOA Groundfish FMP Amendment 41. Beginning in 1998, all trawling was prohibited in southeast Alaska east of long. 140°E (Fig. 3). This MPA, with a total area of 180,418 km^2 (52,600 n.mi.^{2}), includes continental shelf, slope, and basin areas.

The value of the southeast Alaska trawl closure is difficult to evaluate. From a conservation perspective, the MPA appears to have met its objectives of conserving habitat for rockfish. Biomass of Pacific ocean perch in the Gulf of Alaska has increased dramatically in the past decade (NPFMC, 2004b). However, this increase can be primarily attributable to large year-classes produced prior to implementation of the MPA, as well as a reduced harvest rate on exploitable sized fish. From a social perspective, the MPA is viewed as successful by local southeast Alaska fishermen who predominantly target groundfish with longline gear. Interactions between fixed gear (longlines) and mobile gear (trawls) have been eliminated, and concerns about habitat degradation have been addressed. More recently, longline fishermen have begun to develop techniques to harvest species of rockfish that previously could only be harvested in commercial quantities with trawl gear (Falvey[9]).

State Waters Trawl and Goundfish Closures

The Alaska Board of Fisheries has closed extensive areas in state waters to trawling, including areas closed in conjunction with the Federal trawl closures in Kodiak, Bristol Bay, and Cook Inlet described above. These closures are in response to proposals by the public and the Alaska Department of Fish and Game to protect habitats as well as vulnerable species. In the Kodiak area, in addition to the Type I, II, and III Federal areas and Steller sea lion closures, there are year-round bottom-trawl closures enacted in 1986 in state waters surrounding most of the island to protect king and Tanner crabs. The boundaries often follow the 3-mi. limit, except in some cases, particularly along Shelikof Strait, the boundaries extend between points of land, offering protection to embayments. On the mainland across Shelikof Strait, virtually all state waters from the mouth of Cook Inlet along the Alaska Peninsula to Unimak Pass are closed to bottom trawling. Looking eastward to the central Gulf of Alaska, the outer coastal state waters of the Kenai Peninsula from the mouth of Cook Inlet east to Cape Fairfield are closed to groundfish fishing with bottom trawls (Fig. 3).

In the central Gulf, including Prince William Sound inside and outside waters to the 3-mi. limit, bottom trawling is prohibited except for very limited fishing for sablefish. All trawling, including pelagic trawling, is prohibited in large sections of eastern Prince William Sound to protect crabs and Pacific herring gear (Trowbridge[10]).

In state waters of the eastern Gulf of Alaska (east of Prince William Sound), including southeast Alaska inside waters, groundfish trawling requires a permit issued by the Alaska Department of Fish and Game Commissioner. This requirement effectively closes state waters of the eastern Gulf to groundfish trawling with one exception: a very restricted flatfish fishery limited to beam trawls by the Board of Fisheries in 1997 and conducted in four small areas in internal waters of central southeast Alaska. The only other trawling permitted in southeast Alaska is for shrimp, *Pandalopsis dispar,* and *Panadalus* spp., with beam trawls under special conditions. The combined effect of these closures in the eastern, central, and western Gulf of Alaska is that nearly all state waters in the Gulf of Alaska are closed to bottom trawling for groundfish.

In the Bering Sea, in addition to the nearshore Bristol Bay trawl closure described previously, the Alaska Board of Fisheries closed all the major embayments west of Unimak Pass to Umnak Island in the eastern Aleutian Islands to trawling. The Board also closed state

[9]Falvey, Dan, commercial fisherman, Sitka, Alaska. Personal commun. 2005.

[10]Trowbridge, Charles, ADFG, Homer, Alaska. Personal commun. 2005.

waters to all groundfish fishing (including trawling) around St. Matthew, Hall, and Pinnacle Islands in the Bering Sea in 2001. Notably not closed to bottom trawling are state waters in the vicinity of "cod alley" to the north of Unimak Island and all of the central and western Aleutian Islands outside of Steller sea lion protection areas.

Essential Fish Habitat Conservation Areas

In February 2005, the Council and NMFS created several new MPA's to conserve essential fish habitat (EFH) from potential adverse effects of fishing. EFH is defined by the Magnuson-Stevens Fishery Conservation and Management Act as those waters and substrate needed by fish for spawning, breeding, feeding, or growth to maturity. A 2,500+ page scientific analysis was prepared to evaluate the impacts of fishing on EFH, and evaluate alternatives to describe and conserve EFH from fishing impacts (NMFS, 2005). The analysis concluded that fisheries do have long-term effects on habitat, but these impacts were considered minimal and would not have detrimental effects on fish populations or their habitats. Nevertheless, as a precautionary measure, the Council adopted several new MPA's to conserve EFH, and these MPA's were implemented by NMFS in 2006, when approved by the Secretary of Commerce.

Fishery managers were concerned about the effects of fishing in areas with emergent epifauna, particularly corals and sponges that may be vulnerable to fishing impacts. Corals apparently provide protective habitat for several Pacific rockfish species, *Sebastolobus alascanus* and *Sebastes* spp., and Atka mackerel (Heifetz, 2002; Krieger and Wing, 2002), and sponges and other living substrates have been associated with a variety of demersal fish species (Malecha et al., 2005). Research had shown that bottom trawling could damage corals (Krieger, 2000), vase sponges, and other emergent epifauna off Alaska (Freese et al., 1999; Freese 2002), and that the first pass of a trawl may cause relatively more extensive damage than subsequent passes (i.e. "The first pass is the worst pass."). Gorgonian corals were thought to be especially vulnerable, given the longevity of colonies (Witherell and Coon, 2000).

Aleutian Islands Habitat Conservation Area

To address concerns about the impacts of bottom trawling on benthic habitat (particularly on coral and sponge communities) in the Aleutian Islands, the Council and NMFS took action in February 2005 to prohibit all bottom trawling, except in small discrete "open" areas. The concept of freezing the footprint of trawling to areas historically fished, as a habitat conservation measure for the Aleutian Islands, Bering Sea, and Gulf of Alaska, was first evaluated in the Groundfish Fisheries Draft Programmatic Environmental Impact Statement (NMFS, 2001b). This "open area approach" was further developed by Council staff in early 2002 during the formulation of EFH EIS alternatives, and discussed extensively by the Council's EFH Committee. Following the release of observer data by NMFS to the environmental group Oceana in 2002 and their subsequent analysis of the trawl haul locations and bycatch location of coral, sponges, and bryozoans, the group proposed a slightly different set of open areas for the Aleutian Islands (Shester and Ayers, 2005). With modifications to account for data deficiencies regarding trawl locations, the Council adopted this approach in February 2005 as a major component of its habitat conservation program in the Aleutian Islands area. Beginning in 2006, over 95% of the Aleutian Islands management area was closed to bottom trawling (950,463 km^2 or 277,100 n.mi.^{2}), and about 4% (42,611 km^2 or 12,423 n.mi.^{2}) remain open (Fig. 4).

Aleutian Islands Coral Habitat Protection Areas

Additional conservation of EFH in the Aleutian Islands is provided by another set of MPA's, called the Aleutian Islands Coral Habitat Protection Areas. These MPA's includes six sites with especially high densities of corals and sponges (the so-called "coral garden" areas) that were delineated based on submersible observations (Stone, 2005). Beginning in 2006, these areas were closed to all bottom contact fishing gear (longlines, pots, trawls, etc.) and should thus be considered as marine reserves with a total area of 377.3 km^2 (110 n.mi.^{2}) (Fig. 4). To improve monitoring and enforcement of the Aleutian Island closures, a vessel monitoring system (VMS) was required for all fishing vessels. Additionally, a comprehensive plan for research and monitoring will be developed to improve scientific information about this area, and improve and evaluate effectiveness of these fishery management measures.

Gulf of Alaska Slope Habitat Conservation Areas

To conserve EFH in the Gulf of Alaska, bottom trawling for all groundfish species was prohibited in 10 designated areas along the continental shelf, beginning in 2006 (Fig. 5). These areas, which are thought to contain high relief bottom and coral communities, total 7,155 km^2 (2,086 n.mi.^{2}). At the time of the Council's 5-year review of EFH in 2011, the Council will review available research information regarding two of the closed areas (in the vicinity of Sanak Island and Albatross Bank) to determine efficacy of continued closure.

Habitat Areas of Particular Concern

In February 2005, in addition to mitigating potential effects of fishing on EFH, the Council took final action to designate and protect habitat areas of particular concern (HAPC). Identification of HAPC provides focus for additional conservation efforts for those portions of EFH that are ecologically important, sensitive to disturbance, exposed to development activities, or rare. To protect these areas, the Council took action to eliminate virtually all potential impacts due to fishing by prohibiting almost all fishing gear. As a result, these areas should essentially be considered no-take marine reserves. While pelagic fishing would be allowed in these areas, none is anticipated, so resource extraction will be nil in the areas (NPFMC, 2005a).

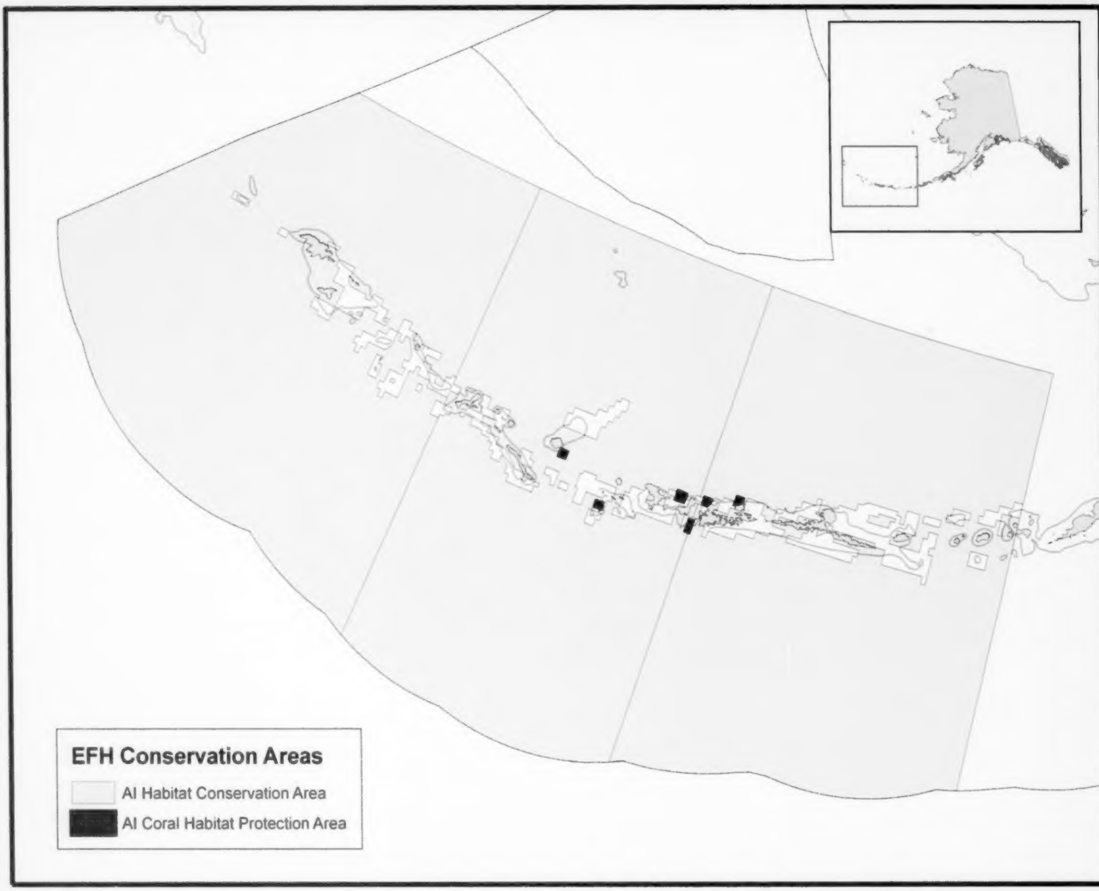

Figure 4.—MPA's proposed to conserve essential fish habitat in the Aleutian Islands area.

Gulf of Alaska Coral Habitat Protection Areas

In southeast Alaska, multibeam surveys and submersible observations have discovered boulder and bedrock substrates supporting dense aggregations of *Primnoa* coral. In an area about 28 km west of Cape Ommaney in southeast Alaska, submersible observations confirmed the presence of several hundred *Primnoa* colonies attached to boulders and bedrock at depths of 200–250 m (NPFMC, 2005a). Many of these colonies exceeded 1 m in height. Dense aggregations of *Primnoa* were also found at similar depths and substrates along the western flank of the "Fairweather Grounds" in the eastern Gulf of Alaska.

To highlight research areas and protect the fragile coral habitats, the Council designated these areas with *Primnoa* as HAPC (Fig. 6). The total size of these areas is 230 km^2 (67 n.mi.^{2}). All Federally managed fisheries using bottom-contact gear (longlines, trawls, pots, and dinglebar gear) was prohibited within five zones of the HAPC area, beginning in 2006. These zones, which total 46 km^2 (13.5 n.mi.^{2}), include the areas where there have been direct submersible observations documenting the presence of *Primnoa*.

Alaska Seamount Habitat Protection Areas

Seamounts are considered to be HAPC areas because they may be unique ecosystems with endemic stocks or species (De Forges et al., 2000), including corals (Tsao and Morgan, 2005), and thus particularly vulnerable to human activities such as fishing. Relatively diverse fish and invertebrate communities have been found on the top and flanks of several seamounts off Alaska (Alton, 1986; Hoff and Stevens, 2005). To protect these unique habitats and ecosystems, the Council voted to prohibit all bottom contact fishing by Federally managed fisheries on the 16 seamounts in the

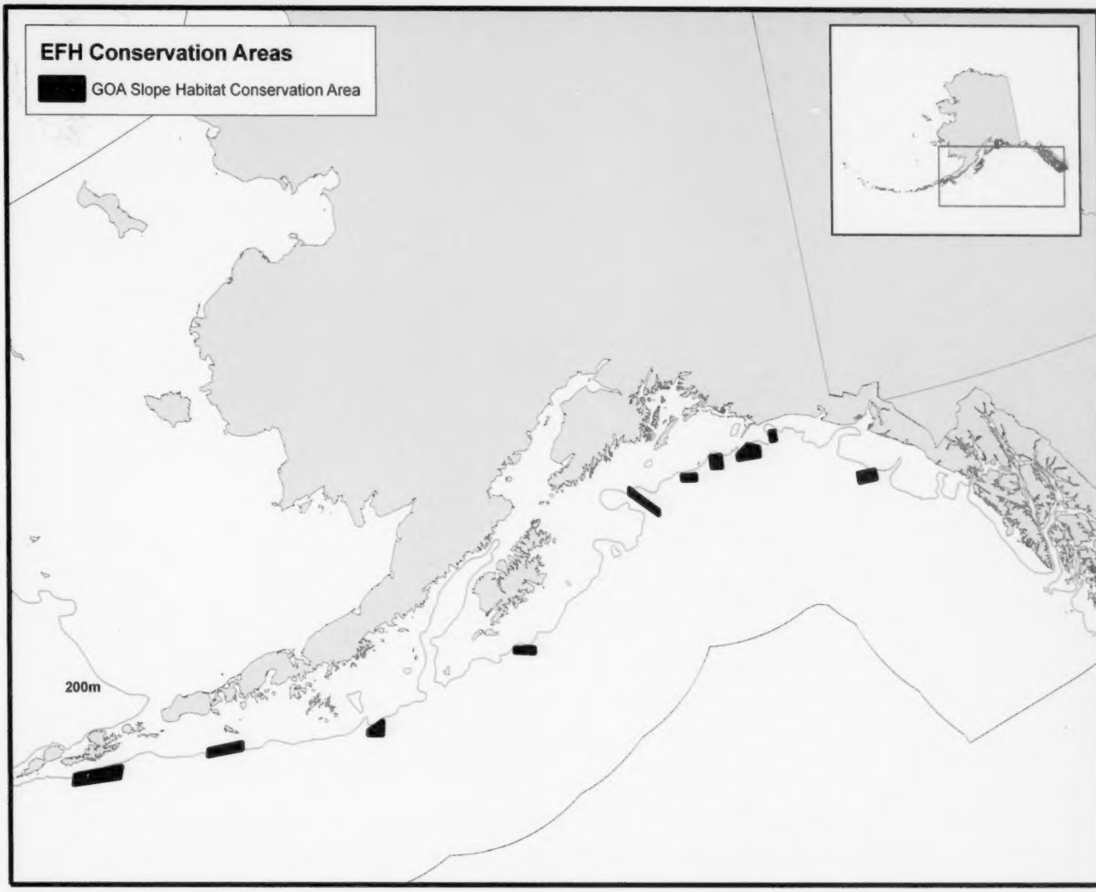

Figure 5.—MPA's proposed to conserve essential fish habitat in the Gulf of Alaska area.

EEZ off Alaska named on NOAA charts: Bowers, Brown, Chirkikof, Marchand, Dall, Denson, Derickson, Dickins, Giacomini, Kodiak, Odessey, Patton, Quinn, Sirius, Unimak, and Welker seamounts. As a group, these MPA's comprise the Alaska Seamount Habitat Conservation Zone with a total combined area of 18,278 km^2 (5,329 n.mi.^{2}) (Fig. 6).

Bowers Ridge Habitat Conservation Zone

Bowers Ridge is a submerged geographic structure that forms an arc extending north from the Aleutian Islands. The top of the ridge rises to less than 200 m from the surface near its southern end, with a deeper area to the north. Although relatively unexplored, the area is likely to include habitats for corals and other living substrates, as well as fish and crab species. As a precautionary measure, the Council voted to prohibit mobile fishing gear that contacts the bottom (i.e. dredges, nonpelagic trawls, and dinglebar gear) within this 18,131 km^2 (5,286 n.mi.^{2}) area (Fig. 6).

Vulnerable Species MPA's

Commercial Salmon Fishery Prohibited Area

The International Convention for the High Seas Fisheries of the North Pacific was signed in 1952. Under the Convention (as amended), Japan agreed to prohibit its mothership salmon fishery from operating within 370 km (200 n.mi.) of the Alaska coast east of long. 175°E (near Attu Island). The intent of this prohibition was to keep the Japanese from competing with U.S. fishermen and minimize harvesting salmon of mixed stock origin. The United States implemented the North Pacific Fisheries Act of 1954 to codify its role in the Convention, thus prohibiting domestic fishermen from fishing for salmon with nets in the North Pacific outside of Alaska waters, except for three historical fisheries managed by the state: False

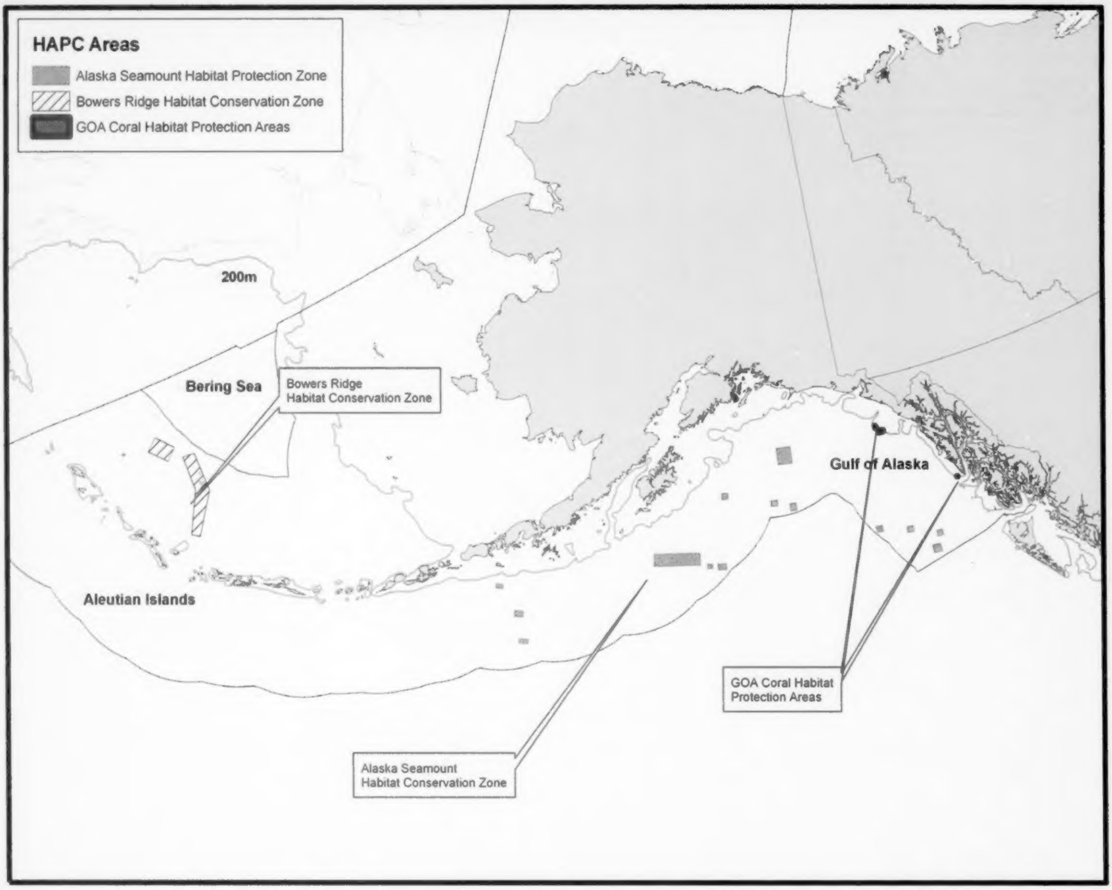

Figure 6.—MPA's proposed to protect habitat areas of particular concern.

Pass, Cook Inlet, and Copper River net fisheries.

The original Salmon FMP adopted this regulation, and prohibited all commercial salmon fishing in the EEZ east of long. 175°E and west of Cape Suckling (long. 144°W), with the above mentioned exceptions. Only troll gear was allowed in the EEZ east of Cape Suckling. In 1990, the Salmon FMP was revised to include the area west of long. 175°E, and prohibit all commercial salmon fishing in that area as well (NPFMC, 1990), thereby increasing the total MPA area to about 5,467,420 km^2 (1,594,000 n.mi.^{2}), not including the EEZ area of the Chukchi and Beaufort Seas (Fig. 7).

Most salmon stocks originating from Alaska rivers (except in western Alaska) increased to high run sizes during the 1980's and 1990's. Although high-seas interception may have affected the run sizes in the 1970's, in more recent years the primary factor influencing run sizes of Alaska salmon is thought to be environmental conditions (Adkison and Finney, 2003).

Chinook Salmon Savings Area

The incidental catch of salmon in non-salmon fisheries has long been a concern to fishery managers and state residents, particularly those in western Alaska who depend on salmon for income and subsistence. The original BSAI Groundfish FMP included provisions that prohibited the retention of salmon. In 1982, the first amendment to the plan established a bycatch limit for Chinook salmon, *Oncorhynchus tshawytscha*, with the available bycatch amounts apportioned to foreign nations with fishing fleets participating in the groundfish trawl fisheries. Once a nation's limit was reached, seasonal area closures were triggered, thus prohibiting that nation's fleet from fishing in the prescribed area. The overall Chinook salmon bycatch limit was further reduced in 1983, but the growing joint venture fleet, and later the fully domestic fishery, offset these reductions.

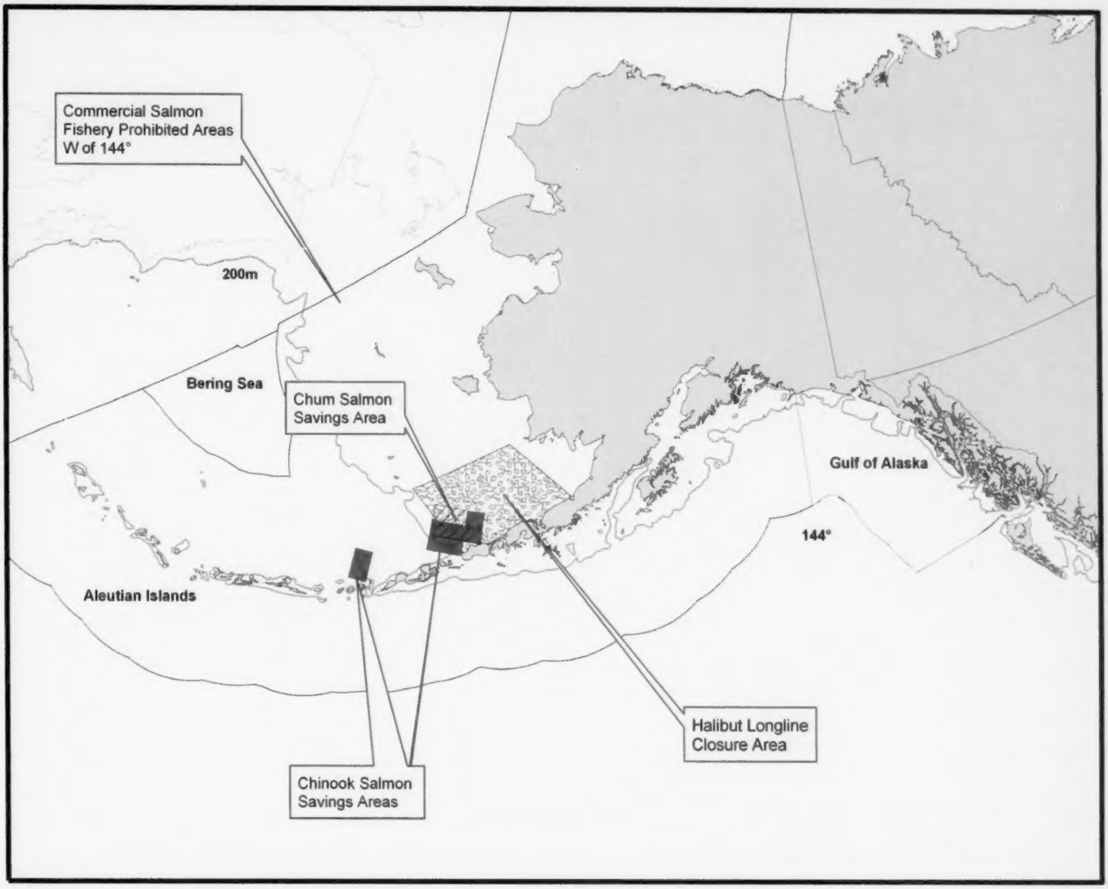

Figure 7.—MPA's designed to reduce impacts on vulnerable stocks of salmon and halibut.

Low Chinook salmon runs in the Nushagak, Yukon, and Kuskokwim rivers in the late 1980's and early 1990's prompted the Council to reexamine measures to control salmon bycatch in groundfish fisheries. Spatial analysis of groundfish observer data provided information on areas that had consistently high bycatch rates of Chinook salmon. In 1995, the Council adopted BSAI Groundfish FMP Amendment 21b, that established three areas in the Bering Sea that would close to all trawling when a bycatch limit of 48,000 fish was taken (Fig. 7). The purpose of the bycatch controls for Chinook salmon was to prevent extremely high bycatch amounts that could raise serious conservation or allocation issues. With the controls in place, Chinook salmon bycatch equated to less than 2.7% of the returning adult population to western Alaska systems (Witherell et al., 2002).

In 1999, the bycatch limit trigger was further reduced to 29,000 salmon taken in the walleye pollock fishery by Amendment 58. In addition, observer data had indicated low bycatch rates of Chinook salmon in the area south of the Pribilof Islands, so this component area of the Chinook Salmon Savings Areas was removed from the MPA (NPFMC, 1999). The prospect of bycatch limits triggering area closures and resulting in forgone catches and added operational costs, provided an incentive for fishing vessels to share information and avoid areas of high salmon bycatch rates, which developed into an industry funded bycatch avoidance program (Haflinger, 2004).

Since the implementation of Amendment 58, the incidental catch of Chinook salmon in groundfish fisheries remained relatively low through 2002. In 2003, nearly 55,000 Chinook salmon were taken as bycatch, thereby triggering closures of the Chinook Salmon Savings Areas for the first time. The closures were triggered again in 2004, a year when over 62,000 Chinook salmon were

taken. It appears that these bycatch levels were likely a result of very high abundance of salmon, as indicated by strong runs of Chinook salmon in the Yukon and nearby drainages in 2003–04, with several escapements near all time highs (ADFG, 2004). Given these high bycatch levels, combined with the fact that the walleye pollock fishery now operates in a cooperative[11] fashion and implements a real-time salmon bycatch avoidance program (Haflinger, 2004), the Council reexamined the regulations and decided it was time to try a slightly different approach to controlling salmon bycatch.

In October 2005, the Council approved BSAI Groundfish FMP Amendment 84 to modify the existing bycatch reduction measures for Chinook salmon and chum salmon, *Oncorhynchus keta*. If approved by the Secretary of Commerce, Amendment 84 will allow the pollock fleet to use their rolling "hotspot" closure system to avoid salmon bycatch. The rolling hotspot system allows the participating fleet to respond quickly given indications of areas of high salmon bycatch and penalizes offenders with weekly area closures if bycatch rates are excessively high (NPFMC, 2005b). Although the regulatory salmon savings area triggers and closures would remain in effect, participants in the rolling hotspot system would be exempted from compliance with savings area closures. Continuation of this exemption would be subject to Council approval and review of the effectiveness of a rolling hotspot system.

Chum Salmon Savings Area

Western Alaska chum salmon runs declined dramatically in the early 1990's, dropping to historically low levels in 1993. In that same year, the incidental catch of chum salmon in groundfish fisheries spiked to a record high of about 243,000 fish. Many were concerned that the trawl fisheries were impacting the salmon returns, and the Council voted to move ahead quickly with an analysis to expand observer coverage on all trawl vessels and to examine the use of area closures to control chum salmon bycatch. Analysis of groundfish observer data indicated spatial and temporal patterns of chum salmon bycatch in trawl fisheries. In April 1994, based on this analysis, the Council requested that NMFS take emergency action to close a 17,150 km^2 (5,000 n.mi.^{2}) area in the southeast Bering Sea once a specified bycatch amount was attained (Fig. 7).

The emergency action was further developed into a permanent regulation, and in January 1995, the Council adopted the Chum Salmon Savings Area as BSAI Groundfish FMP Amendment 35. The Chum Salmon Savings Area is closed to all trawl fishing for the entire month of August (the time of year when bycatch had historically been the highest). In addition, the prescribed area remains closed or closes again after 1 September if 42,000 non-Chinook salmon (virtually all chum salmon) are taken as bycatch in the southwestern area of the Bering Sea.

Bycatch of chum salmon has fluctuated over the years, but until recently it had not reached the levels seen prior to the implementation of this MPA. Average annual chum salmon bycatch was 69,322 during 1990–2001 (Witherell et al., 2002), but it increased every year thereafter to over 465,000 chum salmon in 2004, triggering closures of the Chum Salmon Savings Area during 2002–04 (NPFMC, 2005b). Changes in annual bycatch amounts have been attributed to changes in chum salmon abundance, establishment of the Chum Salmon Savings Area and other regulatory changes, as well as bycatch avoidance measures and operational changes made by the fishing fleet (Witherell et al., 2002).

As previously mentioned, BSAI Groundfish FMP Amendment 84 will allow participants (i.e. the pollock fleet) in a rolling hotspot system to be exempted from compliance with savings area closures. If a cooperative chose not to participate in the system, that cooperative would be subject to the annual Chum Salmon Savings Area closures in August as well as additional closures if triggered. In addition, Amendment 84 would release the nonpollock fleet from the burden of potential closures, given their relatively low contribution to the total number of chum salmon taken incidentally in BSAI trawl fisheries (NPFMC, 2005b).

Halibut Longline Closure Area

Beginning in 1967, the International Pacific Halibut Commission (IPHC) designated IPHC Regulatory Area 4E (Bristol Bay) as a halibut nursery area and prohibited all fishing for halibut year-round within the area (IPHC, 1968). The closure extended south and east of the Pribilof Islands to the westernmost point on Unimak Island. The halibut stock in the Bering Sea had declined to very low levels in the early 1960's, and regulations were being adopted to rehabilitate the stock (reduced fishing periods, prohibition on retention by trawls, minimum size limit, closed areas to longline halibut fishing, and closures to foreign trawl fisheries). The halibut longline closure area was known to have an abundance of juvenile halibut (Best, 1969), and tagging studies done in 1959 showed that halibut migrate from the Bering Sea to the Gulf of Alaska (IPHC, 1978).

At the time this MPA was established, Japanese and Soviet vessels were prosecuting trawl fisheries on the Bering Sea shelf targeting yellowfin sole, other flatfish, and Pacific cod, and the establishment of a halibut nursery area closure may have provided some leverage for the U.S. representatives negotiating bilateral fishing agreements with national governments of foreign fleets. Closure of areas to foreign fleets was the primary management measure used at the time, and the resources targeted by domestic fishermen (halibut, red king crab, and salmon) were of concern for U.S. negotiators (Fredin[2]).

The boundaries of the halibut longline closure area have been modified a couple of times since it was first established (Hoag et al., 1993). The western bound-

[11]The American Fisheries Act of 1998 contained specific provisions for the BSAI pollock fleet to form fishery cooperatives (contractual entities consisting of groups of fishing vessels). Each cooperative receives an annual allocation of quota based on the catch histories of its member vessels. The cooperative allocations end the "race for fish" since each cooperative may fish its quota at any time during the season. Cooperative fishing timing and location choices can be made to improve revenues, reduce operating costs, and reduce bycatch.

ary of the area was moved south and east in 1983 to provide opportunities for halibut fishing in the vicinity of the Pribilof Islands. In 1990, the northeastern part of the closure area was opened to allow halibut fishing opportunities for local Bristol Bay communities. Although adult halibut abundance was low in the area, a study by IPHC suggested that few juvenile halibut would be incidentally captured (Gilroy and Hoag, 1993). The current configuration of the halibut longline closure area is shown in Figure 7.

The benefit of the closure area to the halibut stock has not been fully evaluated. Although the area does contain a fair amount of juvenile halibut, it is unknown to what degree these juveniles contribute to the spawning stock or to the directed fishery. The overall protection for adult halibut provided by the closure may be minimal, because few fishermen would be interested in fishing for halibut there anyway, given the low abundance of adults occupying the closed area (Gilroy and Hoag, 1993). Nevertheless, the area remains closed, and combined with the domestic trawl closures in Bristol Bay, does provide some degree of refuge for juvenile halibut (Williams[12]).

Herring Savings Areas

Most Pacific herring stocks in the Bering Sea declined following the passage of very strong 1977–78 year classes and poor production in subsequent years. Several stocks were projected to decline below minimum threshold levels established for commercial fisheries and potentially affect subsistence fisheries, both of which are important to many western Alaska coastal villages. Further, as the stocks declined, the percentage of the Pacific herring population taken annually by trawl fisheries (particularly the midwater walleye pollock fishery) had increased to 4–7% annually. Given these changes and the importance of Pacific herring to the marine ecosystem, together with associated fishery reductions and concerns for maintaining traditional subsistence herring fisheries, the Council initiated an analysis of measures to control Pacific herring bycatch in trawl fisheries.

In September 1990, the Council adopted Amendment 16a to the BSAI Groundfish FMP, and the regulations were implemented in July 1991. The amendment established a biomass-based bycatch limit for Pacific herring and a series of time and area closures that would be triggered by attainment of the bycatch limit by trawl fisheries (Fig. 8). The bycatch limit was established at 1% of the eastern Bering Sea herring population biomass projection. The limit was further allocated among trawl fisheries, so that attainment of the limit by one target fishery would not impact other trawl target fisheries. The time/area closures established were based on spatial analysis of bycatch rates and the seasonal migration of herring, so the closure areas encompass the times and places where herring are concentrated.

The measures to control herring bycatch appear to be successful, and may have contributed to a substantial reduction in bycatch over time. In 1994, for example, 1,700 t of herring were taken as bycatch; by 2002, herring bycatch had been reduced to only 134 t (NPFMC, 2004a). Closures of the Herring Savings Areas were triggered each year from 1992 through 1995 (Witherell and Pautzke, 1997), but no closures have been triggered in recent years.

Tanner Crab and Red King Crab Bycatch Limitation Zones

The bycatch of crabs in trawl fisheries has been a long-standing issue for fishermen targeting crabs with pot gear. In 1983, bycatch limits for king crabs and Tanner crabs were established for foreign trawl fisheries operating in the Bering Sea. In 1997, domestic fisheries and joint ventures were included in the crab bycatch limit regulations under BSAI Groundfish FMP Amendment 10. The regulations specified Tanner crab bycatch limits for areas east of long. 165°W (Zone 1) and areas west of long. 165°W (Zone 2), and bycatch limits for red king crab in Zone 1 (Fig. 8). Although the boundaries for the zones have not been modified, the bycatch limit amounts have been revised many times (Amendment 12a in 1990, Amendment 16 in 1991, Amendment 37 in 1996, Amendment 41 in 1997, Amendment 57 in 1999).

Bycatch limits have controlled the incidental catch of king and Tanner crabs in trawl fisheries. Directed trawl fisheries, particularly those targeting flatfish species, have been closed in lucrative fishing areas when limits are attained. Closures have been triggered for at least one of the specified trawl fisheries in every year since implementation. However, in more recent years, closures have been infrequent, due in part to changes in the distribution and abundance of Tanner crab and the establishment of no-trawl MPA's in the Bristol Bay area, along with reductions in total allowable catch limits for flatfish species.

Snow Crab Bycatch Limitation Zone

By the early 1990's, snow crab, *C. opilio*, had become the mainstay species of the Bering Sea crab fleet; abundance and prices for this species had sharply increased, while the other crab species had declined. Recruitment of large snow crab, however, had dropped off by 1996, and catch limits were scaled back to 23,133 t (51 million pounds), down substantially from the 1992 limit of 151,045 t (333 million pounds). Crab fishermen claimed financial distress, and requested that the Council limit the incidental take of snow crab in trawl fisheries.

In response, the Council formed a small stakeholder committee, consisting of three crab fishery representatives and three representatives of the trawl sector, to examine available data and recommend a solution. The committee was provided a spatial analysis of survey data for snow crabs, and trawl bycatch data. Their recommendation for a trawl closure area that would be triggered by an abundance-based snow crab bycatch limit, was adopted by the Council as Amendment 40, and implemented in 1998. This area, deemed the Snow Crab Bycatch Limitation Zone, encompasses 308,700 km^2 (90,000 n.mi.^{2}) (Fig. 8).

As an allocation measure, the MPA has eased the concerns of crab pot fishermen regarding the observed

[12]Williams, Gregg, IPHC, Seattle, Wash. Personal commun. 2006.

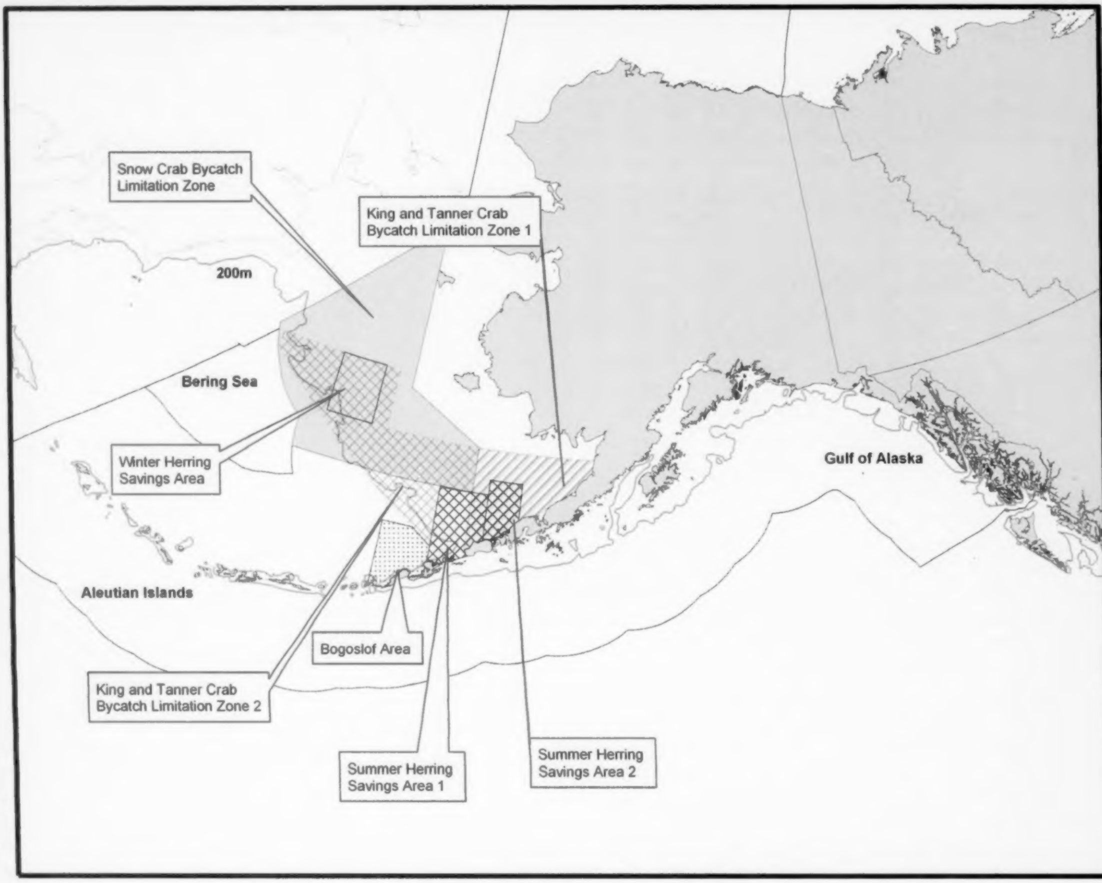

Figure 8.—MPA's designed to reduce impacts on vulnerable stocks of crabs, herring, and pollock.

bycatch of snow crab, although some have expressed reservations about "unobserved mortality" due to trawl gear interactions. Trawl fisheries have adapted to the limits, and to date have not triggered closure of the Snow Crab Bycatch Limitation Zone.

As a conservation measure, the Snow Crab Bycatch Limitation Zone appears to offer only minor benefits, as the bycatch amounts represent less than 0.1% of the population (Witherell et al., 2000). The snow crab stock has declined substantially since 1997 and is currently considered to be below the established minimum stock size threshold due to lack of recruitment (NPFMC, 2004c).

Bogoslof Area

Catch limits for walleye pollock in the Eastern Bering Sea originally applied throughout the management area, but research began to indicate that two separate stocks occupied the Bering Sea. One of these stocks, the Aleutian Basin stock, was projected to decline substantially in the early 1990's. Research had indicated that walleye pollock in international waters of the "Donut Hole" and the Aleutian Basin portion of the U.S. EEZ were the same population and that the area around Bogoslof Island was thought to be the principal spawning area for the Aleutian Basin pollock stock (Dawson, 1989). To prevent the possibility of overharvesting pollock during the 1991 season, the Council recommended emergency action to establish the Bogoslof District with restrictive catch limits.

To further protect the Aleutian Basin pollock stock, the United States passed the Central Bering Sea Fisheries Enforcement Act in 1992 to prohibit U.S. fishermen from fishing in the Donut Hole. Unfortunately, the stock continued to decline, and by the end of the year, all the countries involved in harvesting pollock (United States, Russia, China, South Korea, Japan, Poland) had agreed to voluntarily suspend fishing in the Donut Hole in 1993 and 1994. In 1994,

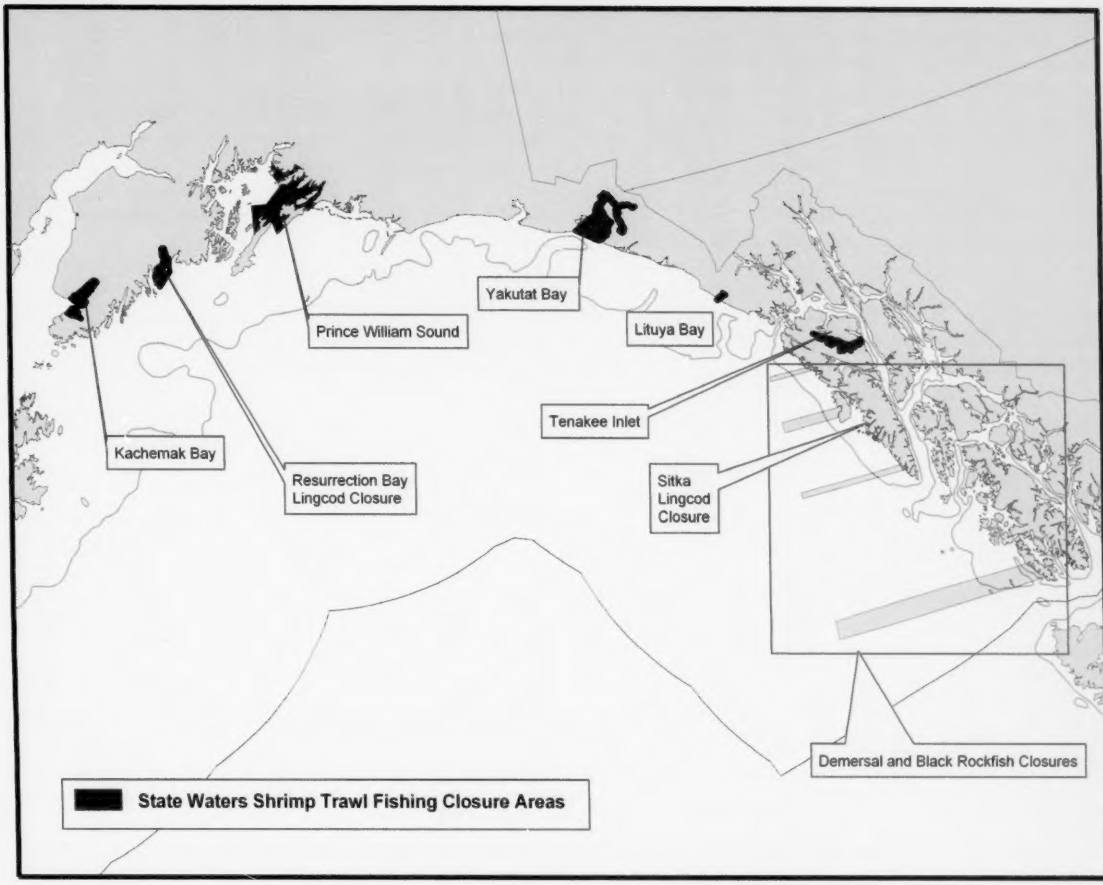

Figure 9.—MPA's designed to reduce impacts on vulnerable stocks of lingcod, rockfish, and shrimp.

all these parties signed the "Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea" to prohibit fishing for walleye pollock until the stock reached a threshold of 1.67 million t. The Convention further specified that the pollock biomass in the Bogoslof area is deemed to represent 60% of the Aleutian Basin pollock biomass. In other words, when the Bogoslof area pollock biomass exceeds one million t, a fishery would be allowed in the Donut Hole.

No pollock fishing has been allowed in the Bogoslof District since it became established in 1992 by BSAI Groundfish FMP Amendment 17. As part of the Steller sea lion protection measures implemented beginning in 2002, all fishing for walleye pollock, Pacific cod, and Atka mackerel was prohibited in the Bogoslof area (Fig. 8). Despite the closure and prohibition on walleye pollock fishing, the Aleutian Basin pollock stock biomass remains at very low levels (NPFMC, 2004b).

State Waters Groundfish Closures

Several groundfish closures in state waters of the Gulf of Alaska were enacted to protect species vulnerable to overexploitation. These include lingcod populations that have proven vulnerable to intense fishing pressure near coastal communities. Two areas were closed to lingcod fishing in the Gulf of Alaska by the Alaska Board of Fisheries in 1997: Resurrection Bay near Seward and most of Sitka Sound (Fig. 9). In a proactive move in 2003, the Alaska Board of Fisheries also closed Sitka Sound and a series of four latitudinal strips on the outer coast of the eastern Gulf of Alaska to commercial harvest of black rockfish, *Sebastes melanops,* where a commercial fishery was developing (Fig. 9). The purpose of this closure was to maintain older year classes, particularly of females that have been shown elsewhere to produce larvae with higher rates of survival (Berkeley et al., 2004). For this

species, the state has management jurisdiction in the EEZ and these closures include Federal and state waters. The Alaska Board of Fisheries also closed Sitka Sound to commercial harvest of demersal shelf rockfish in 1987, as well as areas in the vicinity of Ketchikan (in 1989) and near the towns of Craig and Klawock (in 1991). These closures were to protect heavily exploited populations from directed commercial fishing (O'Connell[13]).

The effects of the state groundfish closures are difficult to assess. The lingcod and demersal shelf rockfish closures likely have had some conservation benefits, although these benefits have not been quantified. The closures have also had some allocation impacts as the resources within these areas were reallocated to recreational users. In the case of the black rockfish closures, the economic effect on commercial fishermen was minimal because the closures were enacted at a time when the fishery in Southeast Alaska was not highly developed.

Shrimp Trawl Closures

The Alaska Board of Fisheries has closed several areas in state waters of the Gulf of Alaska to commercial trawling for shrimp, largely to protect shrimp stocks from excessive exploitation but also to prevent bycatch of crabs and other species. These areas include part of Tenakee Inlet in southeast Alaska, Lituya Bay, and Yakutat Bay, as well as eastern sections of Prince William Sound, and all of Cook Inlet (Fig. 9).

Cultural Resources MPA's

Elsewhere in the United States, cultural resource MPA's are typically shipwrecks, often with historical significance. Alaska has a plethora of sunken vessels, estimated at over 3,000 (McMahon[14]); however, and more uniquely, Alaska has significant subsistence use of marine resources with MPA's designated to conserve some of these uses. Although these MPA's developed for subsistence objectives may not fully meet the MPA Center criteria for MPA's (the primary focus is generally allocation rather than conservation) they are included in this paper because they do have conservation benefits related to preventing depletion of marine resources in local areas. Additionally, they provide access to and sustainable use of cultural resources.

Subsistence Crab Area

The King and Tanner Crab FMP prohibits commercial crab fishing within 18.5 km (10 n.mi.) of King Island, Little Diomede Island, and Saint Lawrence Island. The objective of this MPA is to allocate the nearshore crab resources to local people (primarily Alaska Natives) of these islands who take them for subsistence use. The prohibition on commercial fisheries in this area reduces the potential for discard mortality and the risk of localized overexploitation of crabs in these nearshore areas. Research has shown that the shallow waters (<40 m) around Saint Matthew Island contain high densities of ovigerous female blue king crab; presumably nearshore areas are also important for other populations of blue king crab in the northern portion of their range (NPFMC, 2000).

Subsistence Halibut Regulatory Areas

Areas have been set aside to reduce competition for halibut and ensure access to the halibut resource by local subsistence users. By 1997, increased fishing effort and halibut removals from Sitka Sound by commercial and charter fleets were causing increased competition for halibut and thus creating difficulties for personal use and subsistence fishermen (i.e. the local people who harvest halibut and other fish for food). To address this problem, the Alaska Board of Fisheries appointed a task force of community representatives to prepare a local area management plan. The plan was developed with the objective to reserve access to halibut in Sitka Sound for the fishermen who were not as able to fish outside the Sound, namely the nonguided anglers, and the personal use and subsistence fishermen. In 1998, the Council adopted the plan, and prohibited halibut fishing by all commercial fishing vessels in Sitka Sound, except that vessels ≤10.7 m (35 ft) and charter fishing vessels could fish within the area during June, July, and August. During the remainder of the season, commercial fishing vessels ≤10.7 m (35 ft) are prohibited from harvesting more than (0.91 t) 2,000 lbs. of halibut within Sitka Sound per fishing trip.

In 2001, the Council adopted a halibut subsistence fishery program to legalize the harvest of halibut by Alaska Native and rural Alaskans (both Natives and non-Natives living in rural communities) throughout the state for personal consumption and traditional barter and trade. The program allows harvest of halibut with longline gear, and up to 20 halibut per day can be harvested in most areas. To address concerns about localized depletion of halibut from increased fishing pressure (due to easy access via the road system), the state and Council adopted regulations to prohibit halibut subsistence harvest in most of Cook Inlet waters. This area was already subject to high fishing pressure for halibut from anglers fishing from private and charter vessels. Although subsistence fishermen are restricted within the Cook Inlet area, they are granted new opportunities throughout the remainder of the State's coastal areas.

Subsistence Sea Cucumber Areas

Seventeen areas in state waters of southeast Alaska, including bays or sections of inlets, were closed to commercial harvest of sea cucumbers in 1990 to provide opportunities for subsistence users (Fig. 10). This action was taken following a dramatic increase in commercial sea cucumber landings when the fishery was first developed (Woodby et al., 1993). Closed areas were created in most of the region's fishery management districts. Some of these protect high density sea cucumber habitats, especially in southern southeast Alaska, and were located near subsistence communities. These closures were enacted prior to full development of the commercial fishery in those areas; hence, the economic and social impacts were minor, as status quo was maintained.

[13]O'Connell, Victoria, ADFG, Sitka, Alaska. Personal commun. 2005.

[14]McMahon, D., Alaska Dep. Nat. Resour., Juneau. Personal commun. 2005.

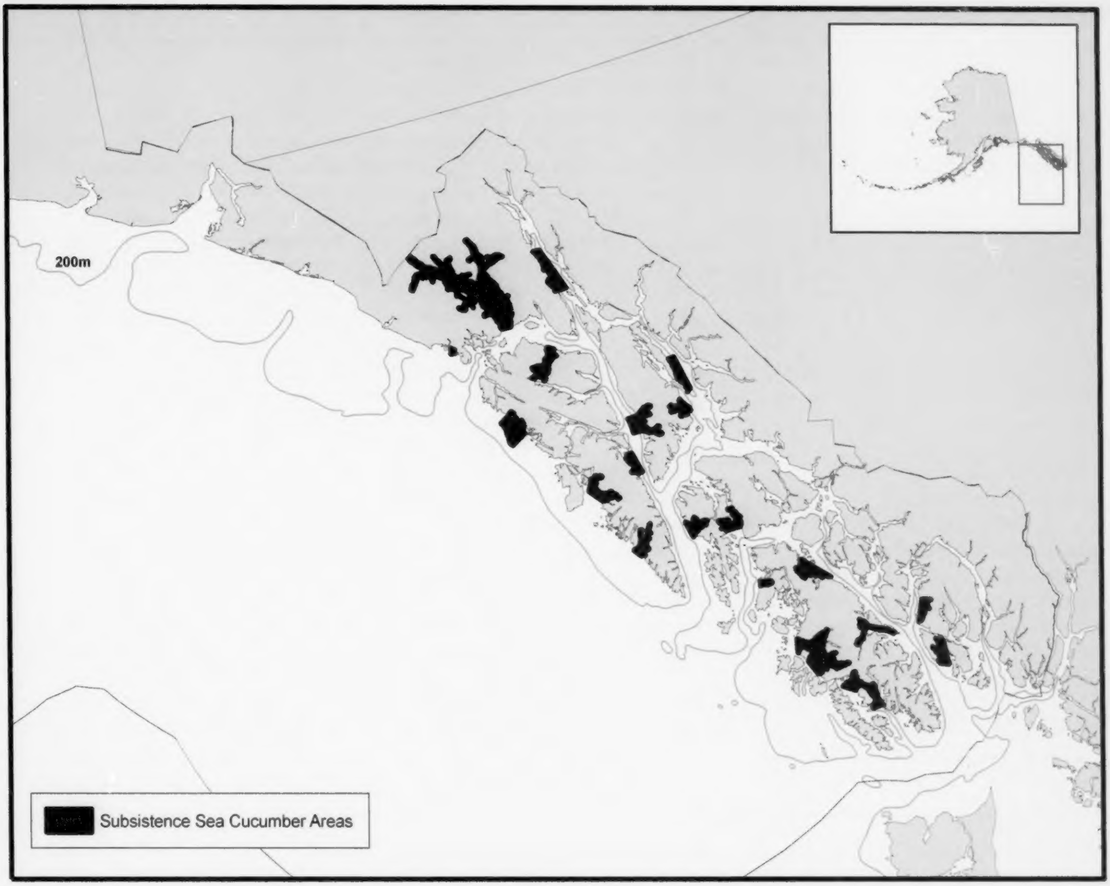

Figure 10.—MPA's designed to protect subsistence opportunities for sea cucumbers.

Discussion

Marine protected areas have been a useful tool to Federal and state fishery managers in Alaska seeking to meet specific goals, such as limiting bycatch of special species, limiting the interaction with marine mammals, and protecting sensitive seafloor habitat from potential damage due to fishing activities. Many of the MPA's were designed to meet multiple objectives. In total, there are currently over 40 named MPA's, many of which include multiple sites. Taken together, the MPA's encompass virtually all Federal waters off Alaska. Most of the MPA's include measures to prohibit a particular fishery or gear type (particularly bottom trawls) within the area on a year-round basis.

In combination with the MPA's established in Federal waters, the numerous and extensive areas in state waters closed to trawling, dredging, or other gear types (Woodby et al., 2002) provide substantial protection for marine resources and their habitats off Alaska. These areas include a wide variety of management measures from limited restrictions on particular fisheries to no-transit zones where all vessels, including fishing vessels, are prohibited from even entering within 5.6 km (3 n.mi.) of all Steller sea lion rookeries along the Aleutian Islands east to Prince William Sound.

In most cases, MPA's have successfully achieved their objectives. Sustainable production has been maintained in the groundfish fisheries, and conservation and allocation issues involving the incidental catch of vulnerable species have been addressed. The success of MPA's at achieving habitat conservation is more difficult to evaluate. Because almost no research has been done to measure benthic changes before and after MPA implementation, we are left to rely on population responses to assess impacts. In some cases (e.g. the Bristol Bay Trawl Closure Area), the positive effects on

stocks can be attributed to some extent on MPA regulations. In other cases, such as the Pribilof Islands Habitat Conservation Area, the signals are mixed. The current environmental regime appears to be preventing full recovery of the Pribilof blue king crab stock, whereas the Pribilof red king crab stock has increased to high levels (NPFMC, 2004c).

Before new MPA's are implemented, cumulative impacts need to be fully considered. Regulations that prohibit or restrict fishing activity in one area are likely to result in additional fishing effort in the remaining open areas, potentially creating other problems. The court-ordered closure of Steller sea lion critical habitat to trawling in 2000, for example, resulted in an increase in bycatch of salmon (Witherell et al., 2002). Other potential effects of implementing additional MPA's include more complex regulations, additional operating costs, and reduced operating flexibility for fishermen.

Evaluation of MPA's after they have been implemented is essential for monitoring performance and to be responsive to new information (Coleman et al., 2004). Several MPA's off Alaska have been reevaluated after implementation, and adjustments made to make them more effective. For example, the Bristol Bay closure area was reevaluated in 1995 relative to its ability to protect juvenile king crab and their habitats, and adjustments were made in the boundaries of the area to encompass the full range of known young-of-the-year habitat (Witherell and Harrington, 1996). In 1999, the Council modified the Chinook Salmon Savings area boundaries after spatial analysis showed that areas of high bycatch rates had changed over the years. More recently, several MPA's in the Gulf of Alaska designed for Steller sea lion protection were modified in response to updated research.

Research is also required to fully evaluate the effectiveness of existing MPA's. For example, the Steller sea lion mitigation MPA's clearly provide some conservation benefits to deep-water coral and sponge assemblages in the Aleutian Islands, but the level of protection has not been quantified. Ongoing direct observations using submersible transects may help provide estimates for coral conservation in the Aleutian Islands (Woodby et al., 2005). Similar research should be done in the other closure areas to evaluate the effectiveness of the existing MPA's at meeting their objectives, and to ascertain other ecological effects of implementing MPA's.

Compliance with MPA regulations off Alaska appears to be very high due to a combination of factors, including strong enforcement presence, an industry-funded onboard observer program, satellite tracking of positions with vessel monitoring systems (VMS), and the availability of alternative fishing opportunities. The U.S. Coast Guard patrols the North Pacific with planes, cutters, and helicopters, and provides regular feedback to the Council on enforcement presence (e.g. number of C-130 flights, cutter days) and offers advice relative to the enforcement aspects associated with MPA's early in the development process. NOAA Enforcement agents also report on violations, including MPA violations. To date, however, very few intentional violations of MPA regulations have been reported.

Compliance is also affected by the presence of onboard observers. The NMFS comprehensive observer program for the groundfish fisheries requires that all vessels larger than 38.1 m (125 ft) (length overall) carry an observer, and vessels 18.3 m (60 ft) to 38.1 m (125 ft) carry an observer 30% of their fishing time. Vessels participating in scallop fisheries and in Bering Sea crab fisheries carry observers as well. Although the observers' primary duties are to measure total catch and discards, they do record vessel positions, and their logbooks can become the basis for prosecution.

VMS is now widely used to monitor fishing vessel positions off Alaska. Regulations require that vessels fishing for walleye pollock, Pacific cod, and Atka mackerel carry an operating VMS at all times. Because nearly all trawl vessels fish for one of these species during the year, and many of the longline vessels fish for Pacific cod, most of the fleet potentially affected by MPA regulations can be monitored by VMS tracking. Lastly, because alternative productive fishing grounds, in most cases, can be found in areas outside of existing MPA's off Alaska, there is reduced incentive for violating the regulations.

The MPA's off Alaska were implemented for specific purposes over time, rather than as part of a comprehensive strategy to establish a network of MPA's as apparently envisioned by Executive Order 13158. The MPA Federal Advisory Committee notes that a national system of MPA's would provide an opportunity for individual MPA's implemented under various jurisdictions to produce benefits that extend beyond individual MPA's, such as improved conservation of broadly distributed species whose life cycles span multiple jurisdictions, conservation and enhancement of biodiversity, and protection of ecologically significant processes (Marine Protected Areas Federal Advisory Committee, 2005). As noted in this paper, the current suite of MPA's off Alaska likely provides these benefits to some degree.

Although no-take marine reserves have been promoted as an ocean conservation tool by many in the scientific and environmental community (Allison et al., 1998; Agardy, 2000; Roberts et al., 2005), fishery managers in Alaska generally have not found a need for such restrictive MPA's, except in special situations to address habitat conservation or marine mammal disturbance issues. Unlike many other areas of the world, the existing management program for Alaska fisheries addresses the objectives for implementing no-take marine reserves as identified by the National Research Council (2001). The ecosystem-based approach utilized off Alaska provides insurance against uncertainty, prevents overexploitation, limits fishing effort, and protects habitats (Witherell et al., 2000). Moreover, extensive unfished areas of the continental shelf, slope, and basin region serve as de facto marine reserves.

Some scientists and environmentalists assert that fully protected marine reserves should be immediately applied as a primary management tool (Lubchenco et al., 2003), covering 20% or more of all biogeographic regions and habitats

(Roberts et al., 2003). We believe that such sweeping measures may not be practical or necessary in all situations. A network of extensive no-take reserve areas, encompassing 20% to 50% of available habitats within each management region off Alaska, was evaluated and considered to mitigate the possibility of the fisheries having a detrimental biological and ecosystem impact, but the network of marine reserves was rejected as unnecessary given the precautionary management program for Alaska groundfish fisheries using more traditional tools (NMFS, 2004b). Although the analysis noted that implementation of such extensive no-take marine reserves, together with quota reductions, may provide positive effects on biodiversity and ecosystem processes, the social and economic impacts to fishery participants and coastal communities would have been devastating (NMFS, 2004b).

Without scientific studies to provide evidence that additional no-take reserves are needed off Alaska to further conserve biodiversity, proposals to implement no-take marine reserves solely for this reason may be viewed with skepticism. Field studies off Alaska to understand the effects of no-take marine reserves on biodiversity and ecosystem processes should be a research priority, and these studies should be developed and conducted in a cooperative manner with fishery participants. Should these studies find that no-take marine reserves enhance long-term sustainability of fish stocks, we would anticipate that fishery managers and the Alaska fishing industry would not only accept, but also actively seek implementation of this management tool.

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Estimating the Economic Impact of the Wild Shrimp, *Penaeus* sp., Fishery: A Study of Terrebonne Parish, Louisiana

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Introduction

Louisiana's commercial shrimp fishermen face many economic and environmental challenges. These challenges are widespread across the Gulf Coast States, but the impact in Terrebonne Parish is significant due to the number of shrimpers in the area. Estrada et al. (2000) indicated that Terrebonne Parish had the largest number of vessel license holders of all Louisiana parishes. According to the Louisiana Department of Wildlife and Fisheries (LDWF), there were over 1,963 vessel licenses in Terrebonne Parish at the end of 2001, including both commercial and recreational vessels.[1]

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ABSTRACT—Two approaches are used to estimate the economic impact of domestic wild shrimp, Penaeus *sp., fishing in Terrebonne Parish, Louisiana. A 2002 survey of commercial shrimp fishermen in the Parish yields information on sales and operating costs, and results are used to estimate a 1-yr sales effect in the Parish of $36.7 to $128.1 million due to shrimp fishing. In addition, 2001 shrimp ticket sales data ($49.9 million) are input into a REMI (Regional Economic Models, Inc.) model built for the 4-parish bayou region of Louisiana. The REMI model forecasts a year 1 reduction in gross regional product (GRP) of $45.9 million in the 4-parish area if the shrimp fishing industry were to disappear in Terrebonne Parish, and an 8-yr cumulative negative impact on GRP in the bayou region of $191.3 million. Study limitations and suggestions for future research are included.*

The Louisiana shrimp industry represents 85% of the value of the State's total edible fishery production (Louisiana Department of Wildlife and Fisheries[2]). For the 20-year period from 1970 to 1990, over 40% of Gulf of Mexico shrimp taken were landed in Louisiana, and Terrebonne Parish, on average, had the highest volume of shrimp landings in the State (Estrada et al., 2000). Over time, this makes Terrebonne Parish a very significant parish/county in the gulf coast commercial wild shrimp industry.

The shrimp industry in Terrebonne Parish has a rich heritage that began in the 17th century with the Creoles and Acadians. Many commercial operations are family owned and have been handed down from generation to generation. These fishermen are born and raised in the area and rarely leave their native hometown (Louisiana Department of Wildlife and Fisheries[2]). They are embedded in the culture of Terrebonne Parish and Louisiana, and they attract many tourists who experience their food, fun, and general way of life.

[1]Louisiana Department of Wildlife and Fisheries. Unpubl. 2001 shrimp vessel license data, commercial and recreational.

[2]Louisiana Department of Wildlife and Fisheries. Louisiana shrimp and shrimping. 2000. Retrieved September 23, 2002. [http://www.wlf.state.la.us/apps/netgear/index].

Shrimping Industry Sectors

Commercial shrimping activities are represented in several sectors (Estrada et al., 2000).

> Shrimper—owns and operates the boats, nets, and any other equipment used in harvesting shrimp and may sell directly to dockside dealer, processor, wholesaler, retailer, and/or consumer. Sometimes, the shrimper may own a processing plant as well.
>
> Dockside dealer—purchases shrimp directly from fishermen, offers services to the fishermen, and some engage in importing shrimp from other countries.
>
> Processor—purchases shrimp from fishermen and/or dockside dealers. They process the shrimp into products useful to the consumer (i.e. frozen, breaded, peeled, dried, etc.) and sell these products directly to the wholesaler or retailer (i.e. grocery stores or restaurants).

Each of these sectors is impacted by changes in catch volume and/or reduced value of the shrimp. The dealers and processors can fill the volume gaps by importing shrimp; however, the local shrimp fisherman has limited options.

This study estimates the economic impact of commercial shrimp fishing in Terrebonne Parish, La. We focus only on the shrimper sector, those who harvest wild shrimp. Two approaches are used to estimate this impact. First, results of a 2002 focus group and survey of Ter-

rebonne Parish shrimpers are presented. Then, the self-reported survey data are used to estimate revenues added to the local economy in a 1-year period. Second, the economic impact over an 8-year period is estimated using a REMI[3] (Regional Economic Models, Inc.) model created for the bayou region of Louisiana. Then, we discuss study limitations and offer suggestions for future research.

The REMI Model

The REMI model is a forecasting system developed by George I. Treyz in order to improve the quality of research-based decision making in the public and private sectors. The model's aim is to answer "what if" questions about the financial impact of economic changes on local regions.

The model's power is in generating estimates of the regional effects of specific changes in an economy over time. The REMI Corporation builds the framework for a model around a specific area or region. This is a key difference in the REMI model, compared to other economic impact models in use. Each model is calibrated to local conditions, using a relatively large amount of local data. REMI models can be used for short- and long-term impact estimations and forecasts, while other models have limited capability for long-term analysis. The REMI models combine several analytical tools to estimate economic impacts: input-output, economic-base, and econometric models. REMI models have been used since 1980.

Economic impact models forecast three types of impacts: direct, indirect, and induced. A direct impact is created by the initial sale of the harvested shrimp, when the customer (dockside dealer or consumer) makes the purchase. Indirect impacts are secondary and are generated by direct impacts. The shrimp harvester spends the revenue from the sale buying goods and services, so the original sale of the harvested shrimp benefits other businesses and industries. Induced impacts result from the wages and salaries paid by both directly and indirectly impacted industries, because the employees of these companies spend their income on goods and services. Induced impacts create a continual cycle of additional indirect and induced effects. The original dollars multiply in the economy.

A model was built by the REMI Corporation for the bayou region of Louisiana (which includes Terrebonne, Lafourche, Assumption, and St. Mary Parishes). This model was used to estimate the impact of the Terrebonne Parish shrimpers on the 4-parish bayou region economy. Total sales of white, *Penaeus setiferus*, and brown, *Penaeus aztecus*, shrimp (heads-on[4]) from the Parish for 2001 ($49.9 million) were input into the model. The model asks "what if the wild shrimp harvesting sector in Terrebonne Parish disappeared from the economy?", deducts these shrimp sales from the overall regional revenues (in the farming, agricultural, and fisheries category), and then estimates the negative impact on the regional economy.

Prior Attempts to Estimate the Economic Impact of Shrimping

Few attempts have been made to estimate the economic impact of shrimp fishing in the United States. None of the prior research focuses strictly on the wild shrimp fishery.

Three studies (Southwick Associates, 1997, 2005; Southwick Associates[5]) report the economic benefits of Louisiana fisheries, wildlife, and boating resources. Their 1997 study yielded a total estimated economic effect from marine shellfish of $1.9 billion in 1996. The 2000 study of fisheries and boating resources in the Acadiana Bay Region of Louisiana estimated a total economic effect from commercial fisheries of $415.6 million in 1999. The Acadiana region includes the coastal waters of St. Mary Parish, Iberia Parish, and the eastern half of Vermilion Parish. The 2005 study of the economic benefits of fisheries, wildlife, and boating resources in Louisiana estimated the economic impact of all commercial fisheries in 2003 at $2.6 billion, and marine shellfish contributed almost $1.8 billion to this impact. All three Southwick studies used the Regional Input-Output Modeling System (RIMS-II)[6] to make these estimates.

The RIMS model was developed in the 1970's by the Bureau of Economic Analysis (BEA) as a method for estimating regional input-output (I-O) multipliers. During the 1980's, BEA enhanced the RIMS model by developing RIMS-II. This model is based on input-output tables, which show the industrial distribution of inputs purchased and outputs sold in an industry. A typical input-output table uses two data sources: 1) BEA's national I-O table shows the input and output structure of almost 500 domestic industries, and 2) BEA's regional economic accounts are used to adjust national tables for a region's industrial structure and trading patterns.

Posadas[7] used IMPLAN 2.0 to estimate the economic impacts due to shrimp harvesting, processing, and distribution in Mississippi at $436,660,000 in 1997. The study includes estimates for the industry's economic impact in 1994 and 1991 ($303,680,000 and $290,010,000, respectively). The IMPLAN model[8] was developed by the USDA Forest Service in the 1970's for use in community impact analyses. In 1995, a new version of the software was developed by the Minnesota IMPLAN Group (IMPLAN 2.0). The second version creates Social Accounting Matrices, which are an extension of input-output accounts. IMPLAN

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[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA. For a discussion of the model, see Regional Economic Models, Incorporated (REMI) Model [www.remi.com].

[4]Statistics are reported for heads-on and heads-off dockside sales in Louisiana. To be conservative, all sales in Terrebonne Parish are assumed heads-on in this manuscript.

[5]Southwick Associates. 2000. The 1999 economic contributions of fisheries and boating resources in the Acadiana Bay region. Unpubl. manuscr. produced for the Acadiana Bay Assoc., New Iberia, La., 11 p.

[6]http://www.bea.gov/bea/regional/rims.

[7]Posadas, B. C. 2000. Output effects of seafood harvesting, processing and distribution in Mississippi. Power Point presentation at Mississippi State University, Coastal Research and Extension Center, 1815 Popps Ferry Road, Biloxi, MS 39532.

[8]http://www.implan.com] and http://www.economics.nrcs.usda.gov/technical/implan/implanmodel.html.

Table 1.— Previous studies of the economic impact of shrimping.

Category	LaFleur, Yeates, and Aysen Economic Impact of Shrimpers in Terrebonne Parish	Southwick (1997) and Southwick (2005) The Economic Benefits of Fisheries, Wildlife and Boating Resources in the State of Louisiana
Population surveyed	Shrimpers in Terrebonne Parish	Commercial fisherman in Louisiana; shrimp and shellfish
Economic model used	REMI	RIMS-II Input-Output model
Sector	Shrimp harvesters	Marine shellfish
Ex-vessel landings (dockside value)	49,997,119	221,100,000 (1996) and 202,040,322 (2003)
Sales	68,827,400	1,500,000,000 (1996) and 1,343,523,357 (2003)
Total economic effect	45,798,068	1,900,000,000 (1996) and 1,791,364,476 (2003)
Labor Income	52,070,000	315,200,000 (1996) and 288,025,817 (2003)
Jobs (no.)	3,108	22,000 (1996) and 20,089 (2003)
Sales tax revenue	667,480	60,400,000 (1996) and 55,212,412 (2003)
State income tax revenues	638,600	14,500,000 (1996) and 13,243,302 (2003)
Federal income tax revenues	Not specified	Not specified (1996) and 82,880,595 (2003)
Source of multipliers	REMI Bayou Region Model	Kearney/Centaur, Inc. 1984. Economic Impact of the Commercial Fishing Industry in the Gulf of Mexico and South Atlantic Regions. Gulf and South Atlantic Fisheries Development Foundation, Inc. Washington.
Conversion factors	Converted 1992 dollars to 2002 dollars using CPI index for All Urban-U.S. Cities Index)	Converted 1995 commercial fishery harvest dollars to 1996 CPI in 1997 study. No conversion in 2005 study; utilized 2003 landings data.
Replicated studies		

[1] Text footnote five.
[2] Text footnote seven.

has been used to analyze conservation projects and programs and to measure the economic and social impacts of these projects (in dollars of sales, local taxes received, and jobs created).

Adams et al. (2002) estimated the economic activities in Lee County, Fla., associated with the San Carlos Island shrimp processing/packing industry. Using IMPLAN 2.0 and three scenarios, these authors estimated direct, indirect, and induced impacts that ranged from $54.96 million in economic output (High Case, optimistic scenario) to a low of $13.48 million (Low Case, conservative scenario).

Table 1 presents an overview of these studies compared to the current study. None of the prior studies focused strictly on the economic impact of wild shrimp fishing on a specific gulf coast economy. Our goal is to address this gap in the literature, using Terrebonne Parish, La.

This research setting provides a significant example of the economic impact of wild shrimp harvesting. Estrada et al. (2000:15,21) report that the State of Louisiana produces more shrimp landings than any other Gulf Coast State, and that Terrebonne Parish has, on average, the largest number of shrimp gear licenses in the state (17.3%) and accounts for the largest percentage (36%) of raw, heads-on shrimp dockside sales in the State.

Perceptions of Terrebonne Parish Shrimpers

To understand the perceptions of Terrebonne Parish commercial shrimpers, a focus group was conducted on 5 October 2002. Seven shrimpers participated, and the focus group served three purposes: 1) identify the range of vessel sizes and cost/revenue variations in the local industry, 2) identify perceived threats to the industry, and 3) obtain focus group information to develop the survey instrument.

Focus group participants believed that threats to the industry are intense and are reflected in the decreasing number of vessels and licensed commercial fishermen. Figure 1 depicts a general decrease in the number of commercial licenses in Terrebonne Parish through 2000. Figure 1 was generated by taking individuals holding any type of commercial shrimp license and reducing it by the percentages of boats <25 feet for resident vessels licensed by holders of shrimp trawl licenses (Horst and Holloway, 2002:

Southwick[1]	Posados[2]	Adams, Mulkey and Hodges (2002)
The 1999 Economic Contributions of Fisheries and Boating Resources in the Acadiana Bay Region	Economic Impact of Seafood Harvesting, Processing and Distribution in Mississippi	Economic Importance of San Carlos Island Shrimp Processing Industry
All commercial fisherman in Acadiana Bay	Shrimp Industry in Mississippi (harvesters, processing, and distribution)	Managers & owners of 4 shrimp processing & packing facilities
RIMS-II Input-Output model	IMPLAN Professional 2.0	IMPLAN 2.0
All commercial fisheries	Shrimp industry	Shrimp industry
46,877,000	Landings and ex-vessel values in 1991, 1994, and 1997	Heads-off landings from 1981–1997
311,722,000	Not specified	Not specified
415,629,000	436,660,000 (1997)	13.48 (low case) to 54.96 (high case) million
66,827,000	82,500,000 (1997)	5.46 (low case) – 22.24 (high case) million
4,660	5,853 (1997)	382 (low case) – 1,555 (high case)
12,810,000	Not specified	Not specified
3,073,000	17,130,000 in indirect taxes (1997)	Not specified
15,133,000	Not specified	Not specified
Kearney/Centaur, Inc. 1984. Economic Impact of the Commercial Fishing Industry in the Gulf of Mexico and South Atlantic Regions. Gulf and South Atlantic Fisheries Development Foundation, Inc. Washington.	Lee. 1986. A Study of the Mississippi Input-Output Model. Mississippi Research and Development Center, Jackson and Minnesota Implan Group, Inc., (1997) Stillwater.	Minnesota Implan Group, Inc.,1997. Stillwater.
Converted 1995 dockside value data to 1999—decreased by 6.93% Took 1995 data and converted 1999 by decreasing by 6.93% which was the decrease in dockside value during that period. Since the 1995 data was for the entire State of Louisiana, it was converted to the Acadiana Bay area by multiplying by the percentage of Louisiana coastline that Acadiana Bay represents.		
Southwick, Robert I. 1997. The Economic Benefits of Fisheries, Wildlife and Boating Resources in the State of Louisiana. Produced under contract for the Louisiana Department of Wildlife and Fisheries.		

Tables 15, 25). Consistent with Horst and Holloway (2002), boats <25 feet are assumed to be recreational boats.

The shrimpers believed the threats include "dumping." Imported, farmed shrimp are allegedly "dumped" (sold at prices less than cost which also means at a price less than native or local wild shrimp) on the docks in Louisiana by primarily Asian and Central American countries. In 2001, imported shrimp products accounted for 88% of shrimp consumed in the United States and 37% of the value of all imported seafood products (Thomas J. Murray and Associates[9]).

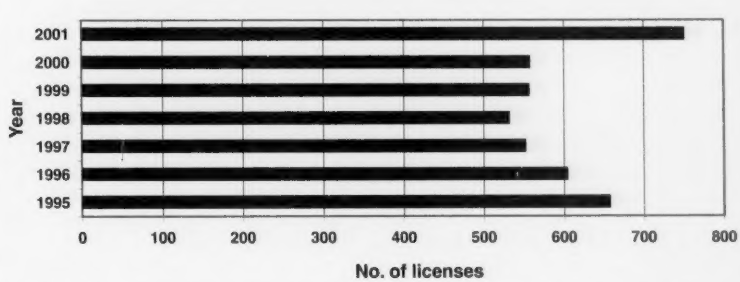

Figure 1.—Commercial shrimp gear licenses for Terrebonne Parish (Net of recreational shrimpers having commercial licenses). Sources: Horst and Holloway, 2002:23,38,40; Holloway, 2003).

Figure 2 represents some recent import trends into Louisiana customs (NMFS[10]). Haby et al. (2003:1) reported that in "1980, the supply of tropical shrimp in the U.S. was 466 million pounds, with the domestic shrimp harvest contributing 44.6% (208 million

[9]Thomas J. Murray and Associates, Inc. 2003. Economic activity associated with the use of imported shrimp in the U.S. Unpubl. manuscr. produced for the American Seafood Distributors Assoc., 20 p.

[10]NMFS, Fisheries Statistics Division. 2002. Silver Spring, MD. Personal commun.

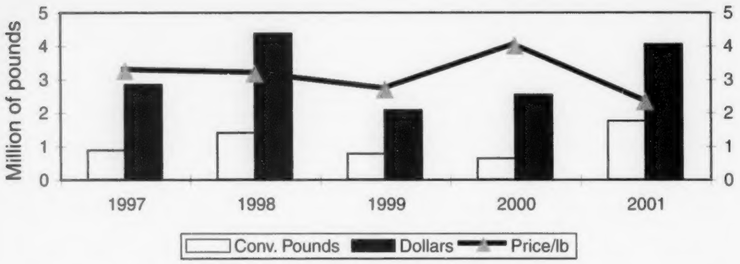

Figure 2.— Shrimp imports into Louisiana customs office (New Orleans). Source: National Marine Fisheries Service query, current data through September 2002.

pounds) to total supply. By 2001, the U.S. shrimp supply had increased to 1.38 billion pounds, with U.S. shrimp fishermen supplying only 201 million pounds, or only 14.6% to the domestic market."

Due to the fact that other countries are less regulated in their production cycles (primarily through shrimp aquaculture) and labor practices, their production costs are much lower. In addition, these operations are being subsidized by their respective governments. Therefore, they can sell their catches to the Louisiana dockside dealers at lower prices, who subsequently sell to the processors at lower prices. This enables the dockside dealer and the processor to lower overall costs. However, it also results in driving down the prices paid for the native wild shrimp catch, which inhibits the local shrimpers from covering operating costs.

One piece of Louisiana legislation authored by State Representative Hunt Downer and signed into law by the Governor of Louisiana is Act 75 of the 2002 Regular Session of the Louisiana Legislature. This Act replaced the severance tax on shrimp harvested in Louisiana waters and imposed an excise tax on all shrimp imported into Louisiana (from other states or from other countries).

Other legislation and litigation being discussed include additional tariffs and quotas on the imported product from foreign countries. An anti-dumping lawsuit was also being formulated by eight states against sixteen (16) foreign nations. The Southern Shrimp Alliance represents the U.S. warmwater wild shrimp fishery from those eight states (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas). Their ultimate goal is to deflect the low-priced, allegedly "dumped," imports by imposing tariffs, quotas, and providing remuneration to those fishermen who have suffered financially due to the "unfair trade practices" (DeSantis[11]).

Swibel[12] has reported that the efforts of the Southern Shrimp Alliance have paid off. In late November, 2004, the Bush Administration finalized duties on Chinese frozen and canned shrimp (28–113%) and on shrimp imported from Vietnam (4–26%). In early 2005, the International Trade Commission found unanimously that six countries (Brazil, China, Ecuador, India, Thailand, and Vietnam) were in violation of U.S. trade laws and imposed trade-weighted antidumping duties of 17.22% on shrimp imports from those countries. Given the 2004 Asian tsunami disaster, the International Trade Commission was to review the effect on the shrimp industries in India and Thailand.[13]

Louisiana shrimpers also believed that regulations on the methods of catching shrimp cause a decreased catch. These regulations include Turtle Exclusion Devices (commonly known as TED's) that protect sea turtles (*Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata,* and *Lepidochelys kempii*) from being caught in the nets, and Bycatch Reduction Devices (BRD's) that protect finfish.

Shrimping laws can be traced back to 1886. Most of these laws address "the delineation of inside-outside shrimp lines, dates for seasons, and regulation or prohibition of certain types of gear" (Chronology[14]).

Shrimpers in the focus group said increases in operating costs pose another threat to the industry. Fuel is certainly one of the most crucial supplies of the shrimper's vessel, and its price fluctuation has become an additional burden. Since 2000 diesel prices have risen from less than $1 per gallon to almost $3 a gallon by mid 2006.

In addition, these shrimpers reported ease of entry into the market by small recreational shrimpers as another threat. The recreational shrimpers are competing in the same waters with small commercial shrimpers who believe them to be reducing their catch.

According to the Louisiana Department of Wildlife and Fisheries[15], the only requirements to obtain a recreational shrimp license are to provide picture identification and/or proof of residency and payment of a $25 fee. Although this type of license only allows use of a ≤16-ft trawl net and imposes a catch limit of 100 pounds or less, a large number of recreational licensees could potentially produce a valid economic threat to small commercial fishermen—whether the recreational shrimper fishes for direct to consumer sales or for subsistence.

Roadside sales of shrimp in the bayou region of Louisiana are common. This suggests that some recreational shrimpers may take their catch directly to the consumer, getting a higher price than that

[11]DeSantis, J. 2002. Shrimpers, attorneys unite to fight imports. Houma Today [http://search.houmatoday.com/apps/pbcs.dll/article?AID=/20020910/NEWS/209100315&SearchID=73256968686459].

[12]Swibel, M. 2004. Crustacean nation. Forbes.com. [http://www.forbes.com/business/2004/12/01/cz_ms_1201beltway.html].

[13]Southern Shrimp Alliance. U.S. shrimp industry wins final antidumping cases against six countries, press release January 6, 2005 [http://www.shrimpalliance.com/Press%20Releases/1-6-05%20ITC%20Final.pdf].

[14]Chronology of Louisiana shrimp laws. 2000. [http://www.wlf.state.la.us/apps/netgear/index].

[15]Louisiana Department of Wildlife and Fisheries. Recreational fishing license information [http://www.wlf.louisiana.gov/licenses/fishing/recreational/].

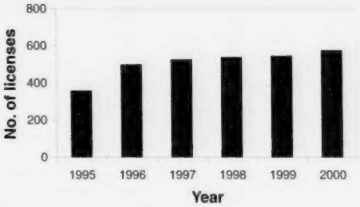

Figure 3.— Increases in recreational shrimp licenses. Source: Horst and Holloway, 2002:40.

offered at the dock. Figure 3 represents Louisiana licenses granted for strictly recreational shrimping purposes (trawls ≤16 ft) and it shows a visible trend of increases in recreational licenses (Horst and Holloway, 2002).

In 2000, about 68.3% (or 1,202) of all resident vessels in Terrebonne Parish licensed by holders of commercial shrimp trawl licenses were <25 ft. Because few commercial shrimp harvesters use vessels under 25 ft, these vessels are assumed to be used by recreational fishermen who have a commercial license. Horst and Holloway (2002) provide this estimate for the state, and the focus group participants supported that estimate. Statistics produced by LDWF indicate that the number of vessels <25 ft registered with a commercial shrimp license for Terrebonne Parish in year 2001 was 1,212 out of 1,963 total commercial licenses, or 63% of all commercial licenses.

These threats to the local shrimping industry and shrimpers in Terrebonne Parish are cause for great concern among those who make this their livelihood. Area shrimpers are convinced that government officials do not realize the shrimpers' true economic impact on the Terrebonne Parish economy.

The shrimp and shellfish industry is estimated to be worth $1.9 billion to the State of Louisiana (Southwick Associates, 1997), and Terrebonne Parish makes an important contribution to the industry. This Parish includes: 17.3% of shrimp gear license holders in Louisiana, 36% of dockside dealers in the State, 38.4% of average annual landings of heads-on shrimp in Louisiana, and 27.7% of average annual landings of heads-off shrimp (Southwick Associates, 1997; Estrada et al., 2000).

The Research Questions

To estimate the local economic impact of the shrimping industry in Terrebonne Parish, we used two approaches:

1) What is the estimated range of a 1-year sales impact on Terrebonne Parish, using revenues reported by local commercial shrimpers in a 2002 survey?

2) What is the estimated economic loss to the 4-parish regional economy, over time, if the shrimping industry disappeared in Terrebonne Parish (estimated for an 8-year period by the REMI Model, using 2001 shrimp ticket data)?

Each approach provides a different perspective on the economic impact of wild shrimp fishing in the area. Survey results provide a "localized positive effect estimate," because the sales reported by participants can be used to estimate total sales revenue added to the Terrebonne Parish economy in 1 year. The modeling approach provides a "regional negative effect estimate," because the REMI model deducts the dockside/shrimp ticket sales in 1 year and then generates estimates of losses in sales, gross regional product, employment and population in that year and for 7 years into the future for the 4-parish bayou region. Two approaches facilitate examination of an important research question as well. To what extent will the sales data provided by Terrebonne Parish shrimp fishermen (subjective, self-reported data) yield estimates similar to those generated by the REMI model (objective, official state data)?

Research Methodology for the Survey of Shrimpers

The population for the study was the commercial shrimpers in Terrebonne Parish. Using information from industry statistics, the Terrebonne Parish population was estimated at 751 commercial shrimpers. The total population (751) was derived by subtracting the percentage of vessels <25 ft in length and licensed to holders of shrimp trawl licenses (62.7% or an estimated 1,212 licenses) from the total number of individuals holding any resident commercial shrimp gear licenses (1,963) issued in the Parish in 2001. This approach follows the logic in the Horst and Holloway (2002) study, which assumed that all full-time or part-time commercial shrimpers have boats >25 ft. The focus group participants confirmed Horst and Holloway's assumption that commercial fishermen utilize boats >25 ft in length.

Surveys were distributed to 26.6% (200 surveys) of the population, using a judgmental sampling method. Members of the sample were not randomly selected; instead questionnaires were distributed by a shrimper/spokesperson to shrimpers owning vessels of differing size. This approach was used to secure the trust needed in the population of commercial shrimpers.

Focus group results were used to generate the questionnaire (Fig. 4). The questionnaire solicited information regarding catch volume, revenues and expenses, vessel size, perceived threats, and other industries impacted by shrimpers. Surveys were hand distributed in the field, during October 2002. About 100 surveys (50% response rate) were returned, representing 13.32% of the estimated population.

Survey Results

Information yielded by the survey questionnaire included boat size, percentage of business devoted to shrimping activities, pounds of shrimp caught, gross revenues, various operating and maintenance expenditures (i.e. fuel, ice, insurance, etc.), perceived environmental and regulatory challenges, and key industries influenced by shrimpers.

Figure 5 illustrates the percentage of respondents by the size of the boat. Most respondents (54%) owned boats >55 ft. Very few respondents used their boats for anything other than shrimping activities (Fig. 6). It would be logical to assume that the larger the boat, the larger the catch. The results in Table 2 generally indicate that as boat size increases, the size of annual catch (heads-on) increases as well.

However, the information gathered for boats >80 ft does not follow this pattern. This suggests four possibilities: less experience in shrimping, less time spent

Survey Questionnaire

In order to gather information on the impact of local shrimpers, please answer the following questions. It will take about 20 minutes. If there is any question that you do not want to answer, leave it blank. Please DO NOT put your name anywhere on this form.

1. **Please put a check mark next to the boat size that you have and tell us the number of boats of that size.**

BOAT SIZE	PUT CHECKMARKS IN THIS COLUMN	NUMBER OF BOATS
20–35 FEET		
36–55 FEET		
56–80 FEET		
81 FEET AND OVER		

2. **What percentage of your business activity is shrimping?** ____________

3. **How many pounds of shrimp did you catch in 2001?**

_____ 0 – 25,000 _____ 100,001 – 125,000

_____ 25,001 – 50,000 _____ 125,001 – 150,000

_____ 50,001 – 75,000 _____ 150,001 – 175,000

_____ 75,001 – 100,000 _____ over 175,000

OR

How many boxes of shrimp did you catch in 2001? __________________

4. **Tell us the amount you spent on the following expenses in 2001?**

Fuel burned _____________________

Ice blocks (include salt) _____________________

Groceries _____________________

Insurance _____________________

Repairs _____________________

Supplies _____________________ (includes webbing, string, shackles, chains, pulleys, paint, rope, oil, gear)

5. **How much labor costs did you pay out in 2001?** ___________________________

6. **How many deckhands and other laborers (include captain) did you hire in 2001?** ___________________________

7. **How much money did you make before expenses in 2001?** ___________________________

8. **Please choose the top 3 problems in the shrimping industry. (1-most important, 2-second most important, 3-third most important)**

_____ Erosion

_____ Propaganda (misinformation)

_____ TEDS/ By-catch reduction devices

_____ Environmentalists

_____ Imported shrimp

_____ Lack of legislative support

_____ Other (please list ____)

9. **What other industries do you think benefit from the shrimpers?**

____

____

____

____

THANK YOU FOR YOUR TIME AND COOPERATION. IT IS GREATLY APPRECIATED!

Figure 4.—The survey questionnaire.

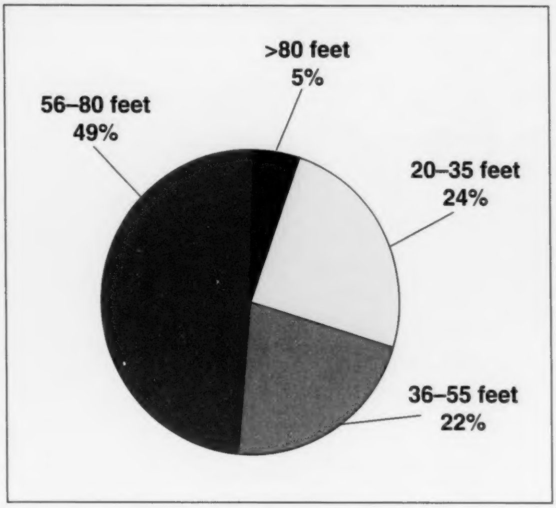

Figure 5.— Percent of respondents by boat size.

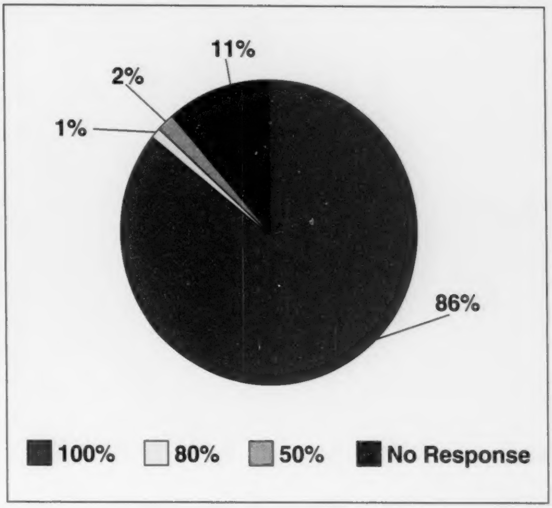

Figure 6.— Percentage of business activity related to shrimping.

on the water, trawling equipment differences (trawlers vs. the use of skimmer and/or butterfly nets), or under-reporting of catch by the largest vessels. The first explanation would confirm an earlier finding by Deseran (1997:8) that "large vessel captains tend to have less years of experience [in shrimping] than smaller vessel captains."

Revenue Trends

Average revenue per boat size as reported by the respondents is presented in Figure 7. Reported revenues more than triple, when comparing a vessel 36–55 ft to one 56–80 ft. A similar pattern is not observed once a vessel exceeds 80 ft.

Expense Trends

Average expenses reported by the respondents include fuel, groceries, insurance, ice, repairs, supplies (boat and gear), and labor (Fig. 8–15). All expense categories are segmented by vessel size, and all mean expenses were calculated using only valid, non-zero responses. These figures generally indicate that as boat size increases, so do expenses. There is one exception to this pattern. Vessels >80 ft report no ice expense, since these vessels have freezers on board.

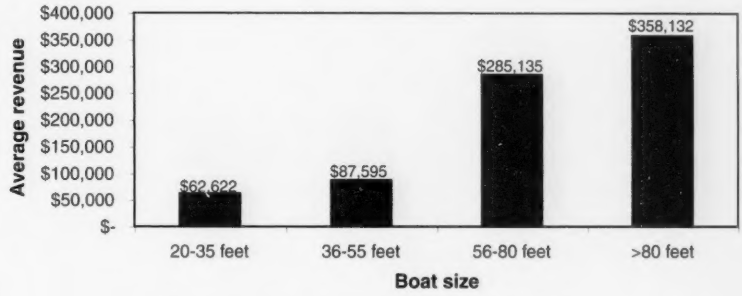

Figure 7.— Average revenue reported by boat size.

Figure 16 illustrates gross profit margin, derived from total revenues and expenses by boat size. Average profit margin was calculated by subtracting total expenses from total revenues, and computing the mean of the result by boat size. Our calculation best reflects a gross profit margin from wild shrimp fishing, after deducting only the expenses reported by the study participants. Profit margins may be overestimated, because the list of operating expenses is not exhaustive.

Population Estimates

To compare the revenue information provided by the survey respondents with

Table 2.—Shrimp catch reported by boat size.

	Percent of Respondents			
Heads-on pounds	20–35 ft	36–55 ft	56–80 ft	>80 ft
<25,000	20.83			
25,001–50,000	62.50	22.73		
50,001–75,000	16.67	50.00	10.20	40.00
75,001–100,000		27.27	2.04	20.00
100,001–125,000				40.00
125,001–150,000			6.12	
150,001–175,000			32.65	
>175,000			48.98	
Total	100.0	100.0	100.0	100.0

LDWF statistics, it was necessary to regroup the survey boat sizes according to the categories reported in the Horst and Holloway study (2002). In the survey questionnaire, the boat size categories

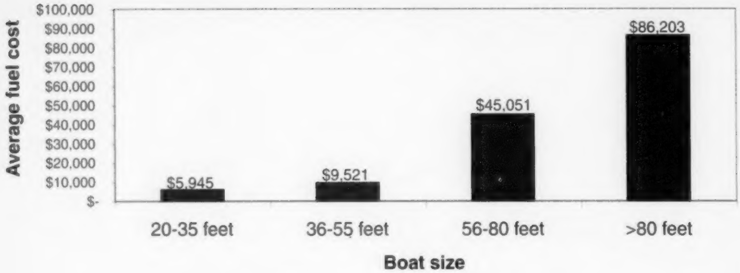

Figure 8.— Average fuel cost reported by boat size.

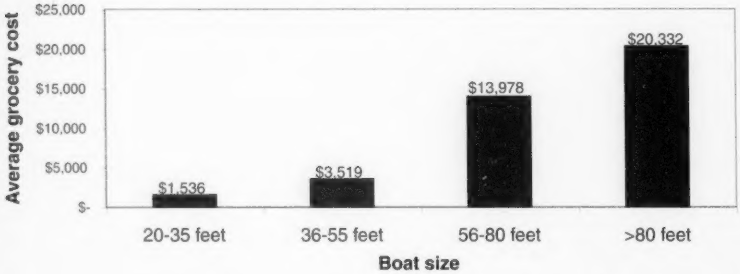

Figure 9.— Average grocery cost reported by boat size.

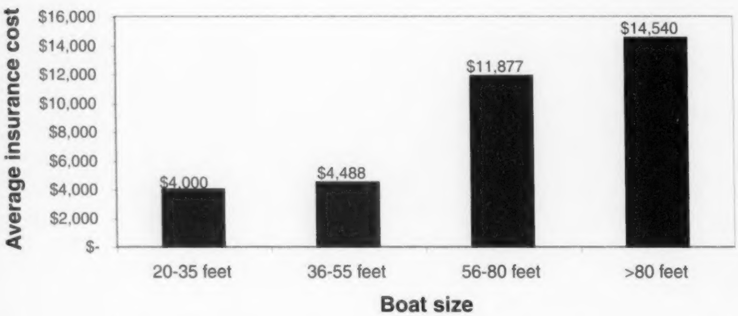

Figure 10.— Average insurance cost reported by boat size.

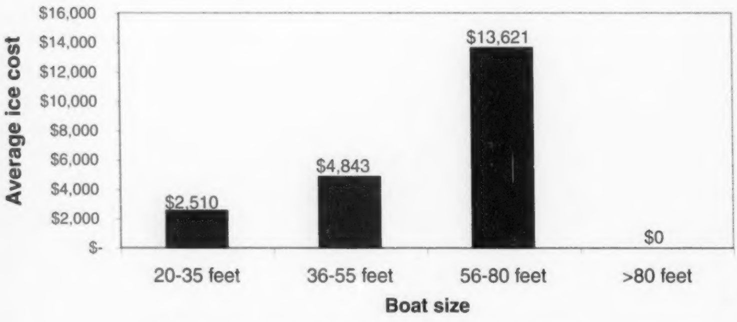

Figure 11.— Average ice cost reported by boat size.

and the estimation of the commercial shrimper population amongst the categories were distributed as shown in Table 3. However, LDWF reports different boat size categories and allocations of the population in Terrebonne Parish (Table 4). Comparing the groupings in Tables 3 and 4, it is clear that large boats (≥56 ft) were over-represented in our survey. Over half of the survey vessels (54%) were ≥56 ft, while LDWF statistics show that in Terrebonne Parish only 16% of the vessels are ≥51 ft.

Therefore, to be more objective as well as to make a proper comparison between the survey revenues and the shrimp ticket sales reported by LDWF, the survey responses were regrouped into two categories to reflect the LDWF boat sizes as best as possible (Table 5). Although there is a small overlap for boats between the sizes of 50–55 ft when recoding the survey groups according to the LDWF categories, it is considered immaterial. There were very few 50–55 ft vessels in the survey group, and these boats were placed in category 1.

Figure 17 represents average survey revenue by regrouped boat size. Using these averages, we were able to estimate ranges of annual revenues for the entire population of Terrebonne commercial shrimpers and segmented by vessel length (Table 6). The ranges were calculated using a 95% confidence interval.

The revenues reported by LDWF for Terrebonne Parish shrimp ticket heads-on sales in 2001 were $49.9 million. If one predicted that 5–15% of catches went unreported for any number of reasons, then the LDWF number may actually be anywhere between $52 and $57 million, and these figures do fall within the confidence intervals estimated in Table 6. The wide confidence interval for all boats is a function of substantial error and variation in the self-reported survey data. This variation could be due to poor bookkeeping practices in the local industry, inadequacies in our measuring instrument, substantial differences in catch that are not explained by boat size, and/or under-reporting of the total annual catch by shrimpers. When survey results are stratified according to the LDWF categories (25–55 ft and >55 ft) the survey

Table 3.—Boat size population estimated from the survey.

	Survey Categories	
Boat size	No. of boats	Percentage of entire population
20–35 ft	182	24
36–55 ft	159	21
56–80 ft	372	50
>80 ft	38	5

Table 4.—Boat size population reported by LDWF.

	LDWF Categories	
Boat size	No. of boats	Percentage of entire population
25–30 ft	274	36
31–50 ft	354	47
51–65 ft	98	13
>65 ft	25	3

Table 5.—Regrouped boat size categories (LDWF).

	Regrouped Data and LDWF Estimates	
Boat size	No. of commercial boats in Terrebonne Parish	LDWF estimate of % in population
25–55 ft	628	84
56 ft and over	123	16

Table 6.—Estimated ranges of revenue for Terrebonne Parish at a 95% confidence level.

	Revenue Estimates	
Boat size	Low	High
25–55 ft	$20,952,681	$ 71,958,120
>55 ft	15,752,678	56,150,932
All boats	36,705,360	128,109,052

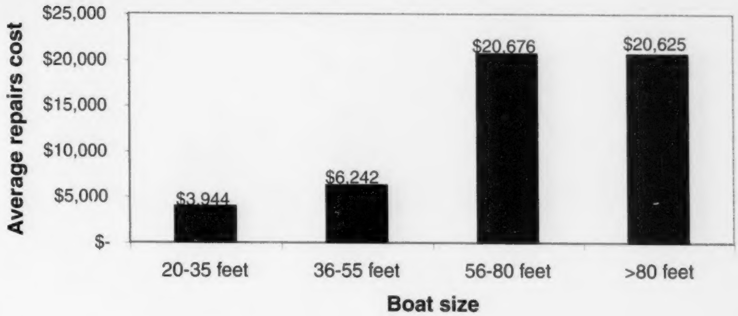

Figure 12.— Average repairs cost reported by boat size.

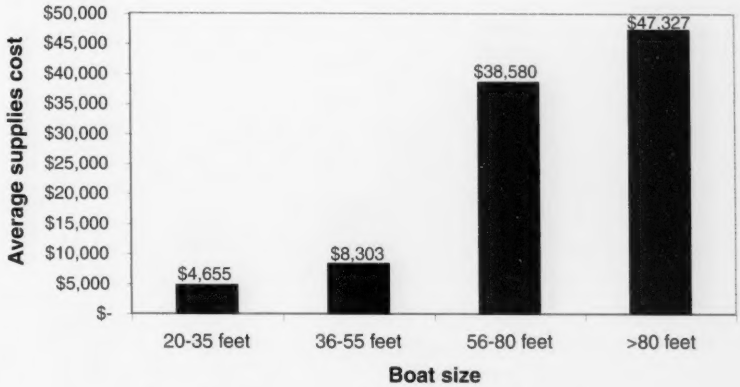

Figure 13.— Average supplies cost reported by boat size.

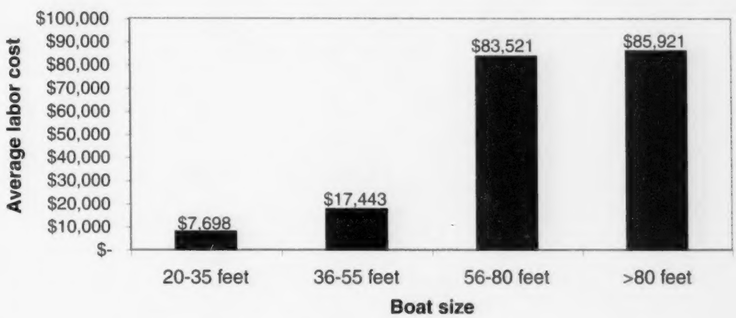

Figure 14.— Average labor cost reported by boat size.

estimates more closely approximate LDWF sales data for the Parish and the confidence intervals narrow. It is interesting that the confidence interval is wider for smaller vessels (25–55 ft) than for larger vessels. This may be due to differences in bookkeeping practices and accuracy, or to productivity differences that exist between vessel categories.

Threats

The shrimpers in the survey also reported perceived threats to the local industry. As shown in Figure 18, imported shrimp, environmental factors, and TED's are perceived as the greatest threats.

Impacted Industries

Shrimpers also reported the top industries impacted by the shrimping industry. These included mechanical and engine repairs, boat suppliers, restaurants and grocery stores, banking, and hardware stores (Fig. 19).

Bayou Region Economic Impact

Our analysis also includes an estimated economic impact on the 4-parish

Table 7.—REMI estimated losses by year.

Category	2003	2004	2005	2006	2007	2008	2009	2010
Loss to gross regional product	(45.8 mil)	(38.87 mil)	(32.55 mil)	(26.30 mil)	(20.76 mil)	(16.31 mil)	(12.28 mil)	(9.29 mil)
Personal income	(34.07 mil)	(41.16 mil)	(46.26 mil)	(49.17 mil)	(50.77 mil)	(51.61 mil)	(51.73 mil)	(51.58 mil)
Population	(233)	(632)	(1,129)	(1,521)	(1,832)	(2,076)	(2,267)	(2,412)
Salaries and wages	(52.07 mil)	(57.26 mil)	(58.95 mil)	(58.47 mil)	(56.84 mil)	(54.73 mil)	(52.01 mil)	(49.30 mil)
Disposable personal income	(27.68 mil)	(34.01 mil)	(38.71 mil)	(41.51 mil)	(43.15 mil)	(44.12 mil)	(44.46 mil)	(44.54 mil)
Employment	(3,108)	(2,939)	(2,789)	(2,638)	(2,500)	(2,379)	(2,251)	(2,142)
Sales	(68.83 mil)	(54.30mil)	(40.45 mil)	(27.44 mil)	(16.28 mil)	(7.57 mil)	.44 mil	6.37 mil

bayou region, calculated by the REMI model. Total annual sales (gross revenues) of catches to dockside dealers, processors, and consumers were taken from secondary sources to demonstrate the amount of business generated by the population. Total annual sales for year 2000–2001 were requested and received by port in Terrebonne Parish from the LDWF (Fig. 20). Figure 21, taken from the National Marine Fisheries Service data query[16], represents all commercial fishery products for a 5-year period, and shrimp represent the majority of the fishery products. As shown in Figure 20, shrimp ticket sales totaled $49.9 million for Terrebonne Parish in 2001 and were used in the REMI economic impact model.[17]

The overall negative impact on gross regional product (GRP) in the 4-parish bayou region is about $45.8 million in the first year (Table 7). This is a very significant economic impact, because the loss of $49.9 million in sales in Terrebonne Parish translates to a reduction in GRP of $45.8 million in the 4-parish bayou region in the first year. In economic impact terms, almost 92% of those dollars remain in the 4-parish bayou region. When those sales are removed from the regional economy, there is almost a 1:1 reduction in the gross regional product of the 4-parish area.

In addition, the REMI model predicts those missing dollars in year 1 cause a series of negative effects on the regional economy over an 8-year time period. For example, the model estimates in year 2003 there would be a negative impact to GRP of $45.8 million; however, this would improve over time to a negative impact on GRP of $9.29 million in 2010. The logic is that over time, individuals who were previously employed in the wild shrimp fishing industry find other forms of work, and some of the lost sales are replaced with other business activities. The impacts over the 8 years (2003–2010) are estimated for other vital economic variables by the REMI model.

Economic impacts derived from the REMI model include sales, gross regional product (GRP), population, and employment estimates. All of these

[16]NMFS, Fisheries Statistics Division. 2002. Silver Spring, MD. Personal commun.

[17]The most recently available official data at the time of the study was 2001.

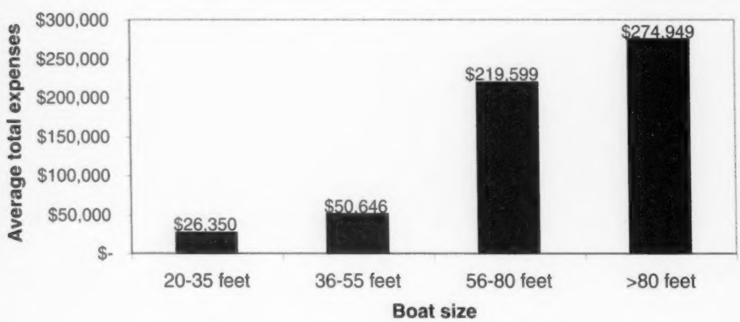

Figure 15.— Average total expenses reported by boat size.

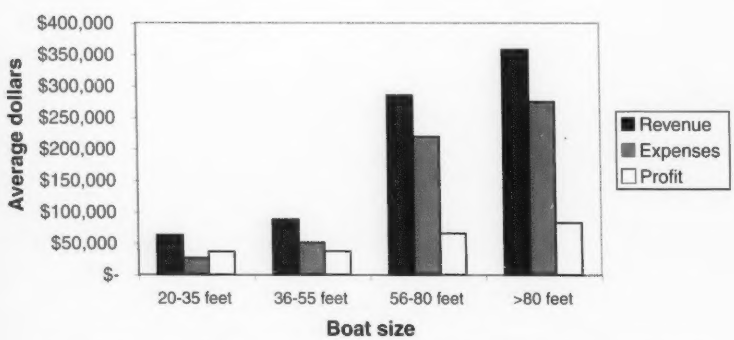

Figure 16.— Average revenues, expenses, and gross profits reported by boat size.

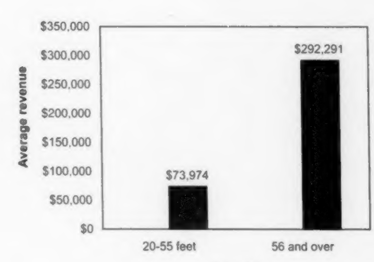

Figure 17.— Recoded average survey revenue.

estimates include any "ripple" or "multiplier" effect from lost shrimp sales. However, the REMI model includes conservative multiplier effects in the forecasts.[18]

Sales impacts refer to the decreases in the dollar value of goods and services sold in the 4-parish region, as a result of the lost shrimping revenue in Terrebonne Parish. The model estimates lost sales of $68.8 million in the first year. While sales estimates are important, only a portion of any "multiplied" sales dollar remains strictly in the region. For example, a shrimper may spend some of the sales dollars to purchase equipment and supplies from companies that are not in the region.

The sales estimates are useful measures, but not necessarily the best measure of economic impact. Gross Regional Product, on the other hand, considers only decreases in the amount of goods and services actually produced (not just sold) in the bayou region, making it a better measure of the negative economic impact. The REMI model also estimates the amount by which full-time, year-round jobs would decrease in the region as a result of the lost shrimping revenue, and forecasts population changes over time.

[18]A discussion of economic impact models is beyond the scope of this manuscript, but there is considerable variation in the multipliers. To compare models, see Rickman and Schwer (1995).

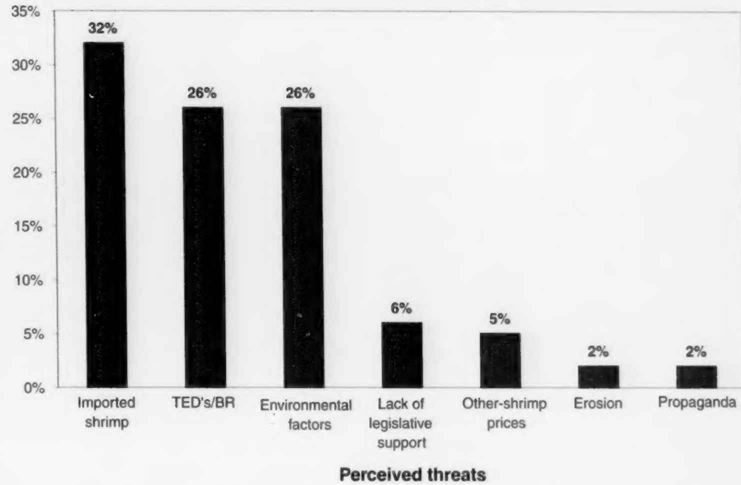

Figure 18.—Perceived threats to the shrimping industry.

In year 1 (2003), the REMI model forecasts a reduction in GRP of $45.9 million in the region, a reduction in regional population of 233 individuals, a loss of over 3,100 jobs, a loss of $52.07 million in regional salaries and wages, and a reduction of $68.83 million in sales.

These negative impacts decrease over time, as "new" businesses and job opportunities slowly replace the lost shrimping revenues. The forecast clearly indicates an important negative economic impact on the bayou region economy if the shrimp harvesting industry disappeared in Terrebonne Parish. The REMI estimates (2004–10) are not adjusted for inflation, so dollars lost would be smaller in years 2004–10 (all estimates in Table 7 are calculated in 2003 dollars).

To more accurately reflect GRP losses over time, the estimates for years 2–8 were discounted at 7%. The annual losses in GRP, and the cumulative loss to the bayou region economy over the 8-year period are:

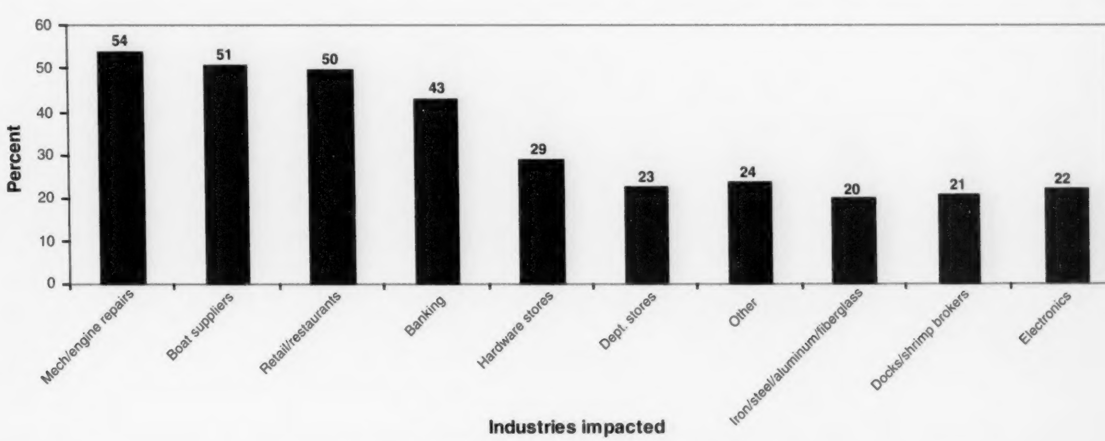

Figure 19.— Other industries impacted by shrimpers.

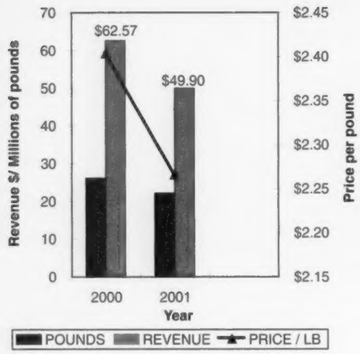

Figure 20.—Dulac-Chauvin ports, only white and brown shrimp revenues in pounds. Source: Louisiana Department of Wildlife and Fisheries

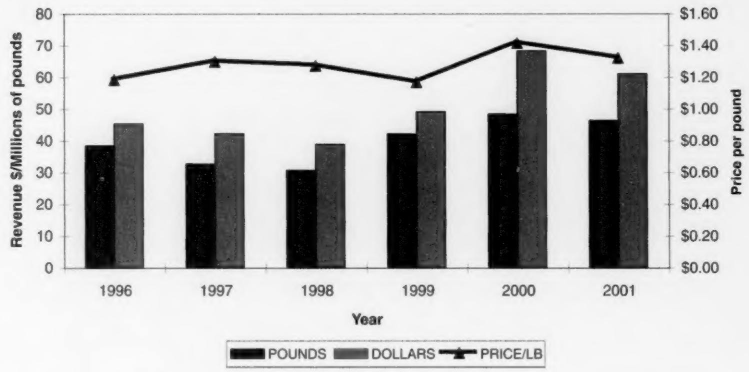

Figure 21.—Commercial fishery landings for Dulac-Chauvin ports. Source: National Marine Fisheries Service data query.

2003	$45.8 million
2004	$36.2 million
2005	$30.3 million
2006	$24.5 million
2007	$19.3 million
2008	$15.2 million
2009	$11.4 million
2010	$ 8.6 million

The cumulative discounted loss to GRP in the bayou region over the 8-year period is estimated at $191.3 million. In addition, increasing population losses over the 8-year period parallel increasing losses in personal income, and disposable personal income over time.

Scope and Limitations

The study results apply to wild shrimp fishermen in Terrebonne Parish, La., who had commercial gear licenses in 2001 and owned boats ≥25 ft. Secondary information used as input in the REMI Model was the most current available and was from year 2001 as provided by LDWF. Economic impact estimates apply only to the shrimper sector, because dockside handlers and processors were not included in the study. However, they are also part of the overall economic impact, so the total impact of the shrimp industry in Terrebonne Parish is much larger than our estimates.

The results have several limitations. Time was a major limitation. Due to the unavailability of local shrimpers, a longer time period would have allowed other data collection alternatives. Because this study was performed during the shrimping season, many of the shrimpers were offshore and unreachable. Even though the response represented 13.32% of the total estimated population, serious questions remain regarding the representativeness of the sample group.

Members of the sample were not randomly selected; instead a judgmental method was used. Questionnaires were distributed by a shrimper spokesperson, who hand delivered the surveys to local shrimpers. This was critical to the success of the study, in that there is a significant lack of trust among the shrimpers when giving sensitive information to outsiders. The distributor Chauvin, a shrimper herself, was able to gain their trust by explaining the importance of collecting accurate and relevant data. However, she reported much hesitancy among those being surveyed in offering information, nonfamiliarity with financial information, and a general disbelief that such a project could offer a benefit to the shrimpers. This poses a second threat to the validity of survey results and estimates.

We were unable to get information from more shrimpers in each boat size category, and this limits the representativeness of the sample. The majority of the respondents owned vessels >55 ft, and larger vessels are overrepresented.

The lack of secondary data on Terrebonne Parish and the state-wide industry was another limitation. As a result, it was difficult to evaluate trends specific to the area.

There is a great deal of state-wide data available from the National Marine Fisheries Service; however, it only reports the revenue side. The only data that could be obtained for the Parish was revenue by port. Until costs and profits are reported, it will be difficult to paint a comprehensive financial picture of the industry in any state. In addition, our instrument measured specific costs and is not exhaustive. While survey results provide some information on the operating costs in the sector, these results should be viewed as an initial attempt to analyze cost structure and profitability.

Focus group participants hinted that catches from smaller boats might not get reported consistently on the trip tickets, as many of these catches are sold directly to the consumer by the shrimper. Therefore, trip ticket information may be understated, which, in turn, would result in the economic impact being understated by the REMI model. Also, this study concentrated on Terrebonne Parish. The findings should not be construed as being representative of any other parish in the State of Louisiana.

The REMI economic impact model did not have a specific category for the occupation of the shrimper. The category used was that of farming, agriculture,

and fisheries, which may or may not be specific enough to precisely model the impacts that changes in the shrimping industry have on the bayou region economy.

Future Research Recommendations

LDWF should continue its statewide study (Estrada et al., 2000) of the shrimping industry which was interrupted due to inadequate funding. This would allow the collection of extensive demographic information about distribution channels, business arrangements, sales volumes, cost of operations, and significant changes in the industry. The continuance of this research would assist in a fuller understanding of the shrimping industry. It would also facilitate statewide and parish-specific economic analyses in future studies.

Research is needed to estimate the total 8-state economic impact of the domestic warmwater shrimp harvesting industry. Reliable data will be imperative to this research. However, for data to be reliable all catches must be properly recorded on trip tickets. This includes cash sales directly to the consumer. If this can happen, then the 8-state coalition would have a better chance of demonstrating the economic impact of the industry.

Annual shrimp landings over the past 20 years were reviewed in connection with the implementation of state and Federal laws. Although it appears that annual poundage for the Dulac–Chauvin ports have continually decreased as laws became more restrictive, much more study is needed. Many other factors could cause this decrease in poundage as well, such as environmental factors, habitat factors, and an increase in recreational licenses.

Efforts are needed to create local coalitions of shrimpers, which could assist in data collection efforts for the Louisiana Shrimping Association, LDWF, and the National Marine Fisheries Service. This would be one way to build trust and create an environment of collaboration between the fishermen and the agencies.

As one reviewer noted, research in this field creates a dilemma for the researcher. While probabilistic sampling approaches are statistically more valid, they may not be feasible and may yield limited data due to trust problems. When non-probability sampling methods are used (as in the current study), higher response rates are achieved but at the price of questionable estimates.

Future research efforts are needed to standardize measurement categories and definitions. Our focus group generated 4 categories of vessels based on length, and those vessels lengths were not consistent with the categories used in other studies or by LDWF. However, only one focus group was conducted with 7 participants. More focus group research might have clarified these measurement problems prior to the survey. Any data collection effort should include the development of standard definitions for the data being requested; in the focus group, it was challenging to gain consensus on terms and definitions.

As a starting point, standard boat size categories should be developed. Several researchers have proposed that boats <25 ft should be considered recreational and not commercial in this industry. But if the industry is as entrepreneurial and "Mom and Pop" as it appears, then excluding these vessels results in underestimating the true economic impact in a region or state. This is particularly important when evaluating total shrimp sales in an area.

The authors believe that many "recreational" shrimpers engage in commercial activities, and this is especially true in the region studied. Shrimping is not only a business in the bayou region of Louisiana—it is a deeply embedded part of the culture, the cuisine, and the way of life. Both the fishermen and a number of individuals who work in the industry in Louisiana agree that all catches are not reported.

Research is needed to examine productivity issues in the wild shrimp harvesting sector as well. Although it is logical to assume that catch increases as vessel length increases, there are many other factors to consider. Time spent on the water, the type of harvesting equipment (trawler vs. skimmer or butterfly nets), variations in the incomes of vessel owners, and higher operating costs for larger vessels can explain differences in catch as readily as vessel length. It is important to understand the interaction of these factors when evaluating productivity.

In addition, a real effort to standardize reporting of costs is needed. For example, vessels <80 ft reported the cost of ice; even though a vessel >80 ft has refrigeration equipment and no ice cost, there is an increased fuel cost. Other costs, such as interest on financed vessels or gear costs should be reported as well. All labor costs should be reported, especially the shrimper's cost of "family labor." One approach would be to record family labor hours, and to associate the going wage in the region with these hours. Then, family labor would no longer be a hidden cost in the sector. Without standardized reporting of revenues and costs, it is impossible to paint a comprehensive financial picture of the industry—or of any individual operator.

Finally, research is needed that compares the taste of wild shrimp to that of imported and pond-raised shrimp. The wild shrimp harvesters believe this is an advantage of wild shrimp that should result in higher prices for their product. Haby et al. (2003:25) state that "wild-caught shrimp have a flavor profile that results from two factors that cannot be duplicated in pond systems." If consumers perceive a superior taste in wild shrimp, then a superior quality image can be developed and marketed for wild shrimp. A branding strategy based on this quality difference could mitigate the threats of increasing imports and low prices to wild shrimp fishermen.

Acknowledgments

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